Color Stability of Different Aesthetic Archwires after Soaking into Tea and Pepsi Cola (An in Vitro Study)

A Thesis Submitted to the Council of The College of Dentistry, University of Baghdad in Partial Fulfillment of Requirements for The Degree of Master of Science in Orthodontics

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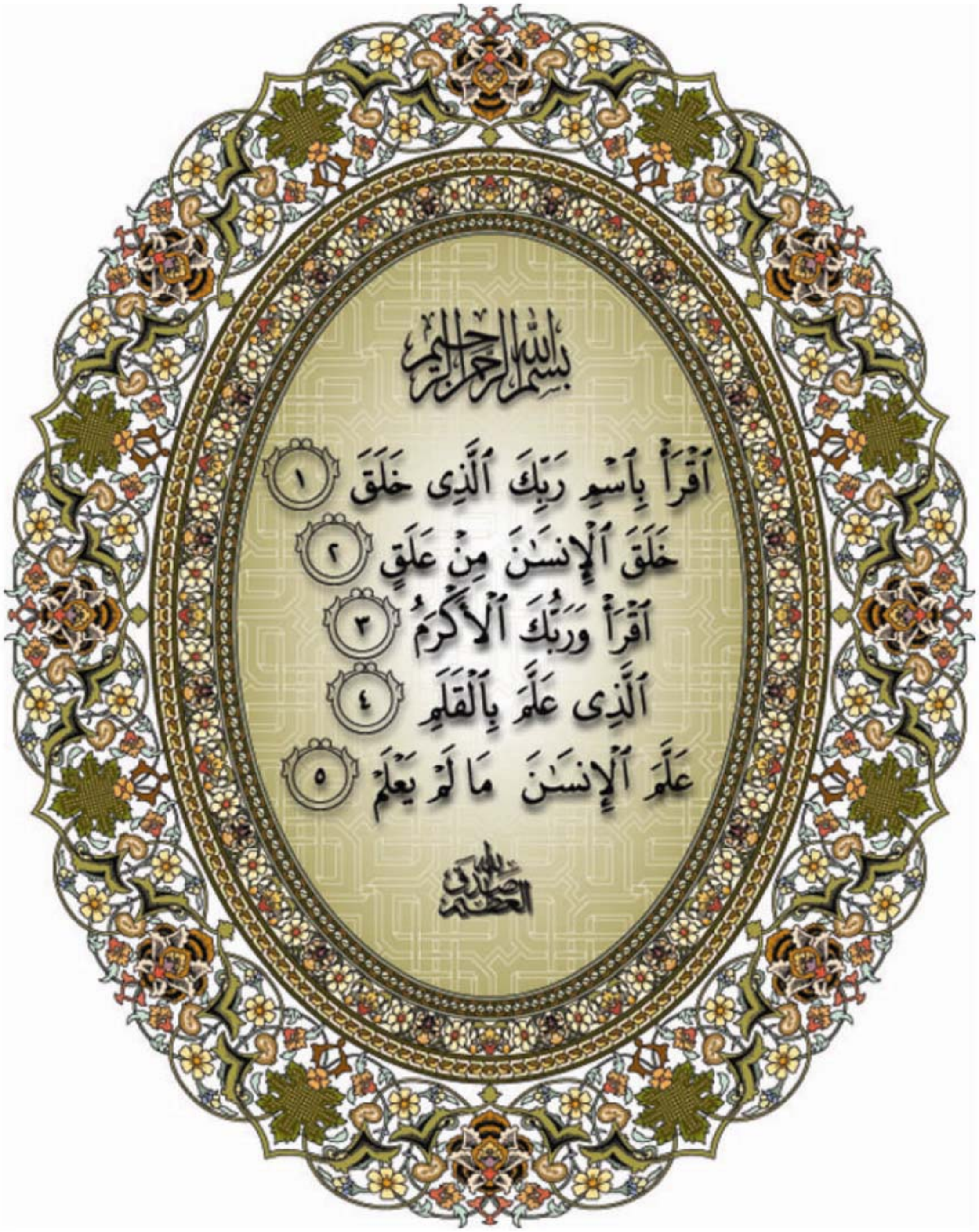
2014 /October **1435 / Thul-hijjah**



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صدق الله العظيم

سورة العلق : الايه 5-1

Supervisor Declaration

This is to certify that the organization and preparation of this thesis have been made by the graduated student ***Zainab Thaer Noori*** under our supervision in the College of Dentistry, University of Baghdad in partial fulfillment of the requirement for the degree of Master of Science in Orthodontics.

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Certification of the Examining Committee and the Signature of the Dean

We, the members of the Examining Committee, certify that after reading the thesis and examining the student ***Zainab Thaer Noori*** in its contents, we think it is adequate for the award of the degree of **Master of Science in Orthodontics.**

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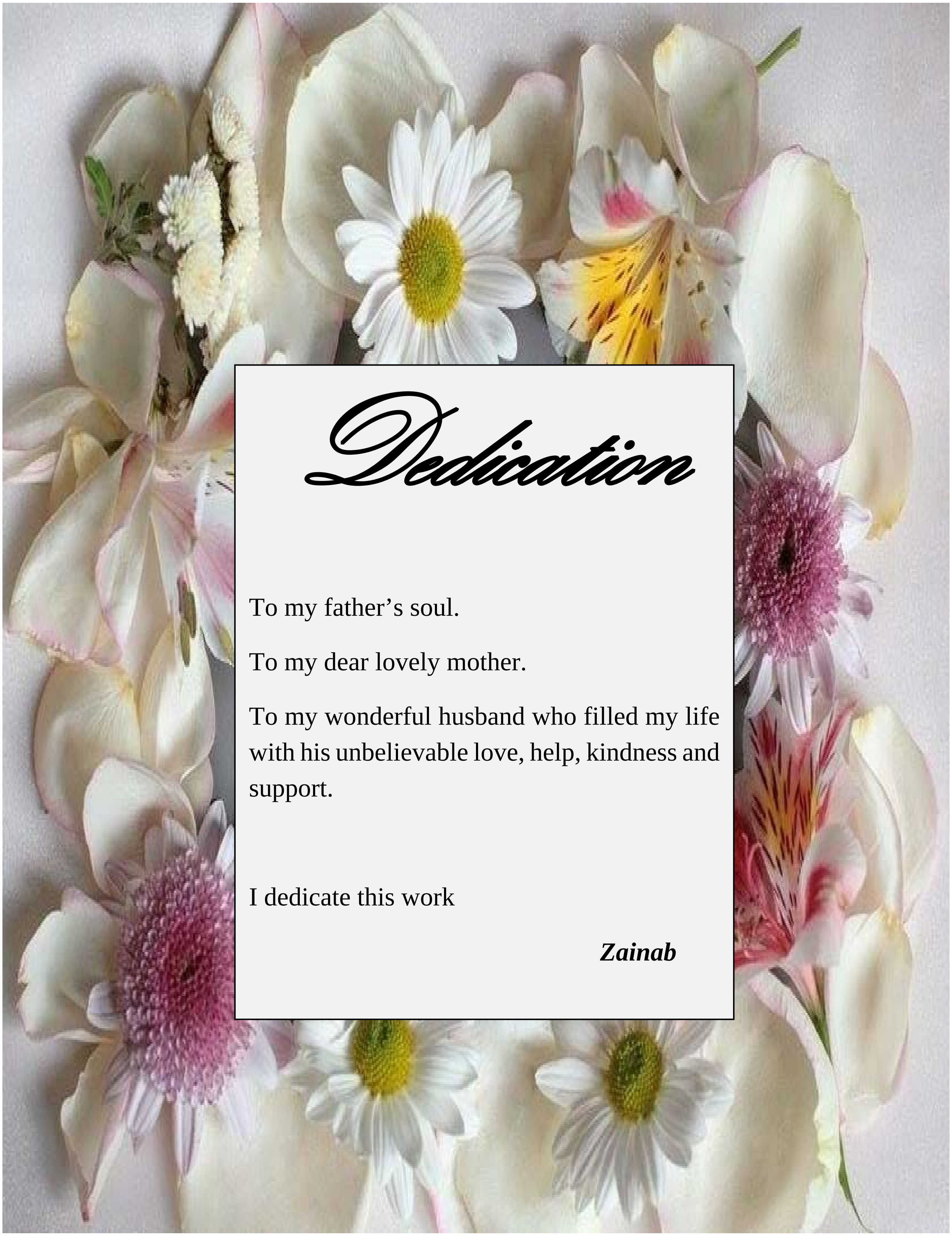

Dedication

To my father's soul.

To my dear lovely mother.

To my wonderful husband who filled my life with his unbelievable love, help, kindness and support.

I dedicate this work

Zainab

Acknowledgement

*First of all, I thank "**Allah**" almighty for granting me the will and strength to accomplish this research and I pray that his blessings upon me may continue throughout my life.*

*I offer my sincere gratitude to **Prof. Dr. Nabeel Abdul Fatah**, the Dean of College of Dentistry, University of Baghdad, for continuously supporting the postgraduate students and for his fatherhood, generosity and care for me personally and for him I am eternally grateful.*

*My deepest gratitude and appreciation goes to my supervisor, **Prof. Dr. Nidhal H. Ghaib** the Chairman of Orthodontic Department who covers me with her motherhood feelings, great support and help during the whole study period. Her advices and generosity with me would never forget and I'm really appreciative to be one of her student.*

*My respect and gratitude goes **to Prof. Dr. Ausama Al-Mulla** for his kindness, support and fatherly care during the study.*

*My appreciation is further extended to **Prof. Dr. Fakhri A. Al-Fatlawi,** for unlimited teaching efforts, cooperation, and advices through the orthodontic course and for being generous with his knowledge and experience.*

*Deepest thanks to **Prof. Dr. Akram Al-Huwaizi**, for his scientific support, encouragement and advices in theoretical and clinical courses of my study.*

*Words cannot and will not be enough to thanks **Assist. Prof. Dr. Iman Al-Sheakli & Assist. Prof. Dr. Hadeel Al-Hashimi,** My big and deep appreciation goes to their efforts, attitudes, support and scientific advice and I am extremely grateful to for their valuable time and effort during the clinical course of the study.*

*I would like to express my respect and gratitude to **Assist. Prof. Dr. Dhea'a Ja'affar, Assist. Prof. Dr.Sami al joboori, Assist. Prof. Dr. Ali Ismail Al-***

Bustani, Assist. Prof. Dr. Mushriq Fawzi, *and to all postgraduate teaching staff for their efforts in teaching, advice, and consultation in the theoretical and clinical programs during the study courses.*

I wish to express my warm appreciation and deepest gratitude to ***Assist. Prof. Dr. Mustafa M. AL-Khatieeb*** *for his advisements and big help.*

Deepest thanks to **Dr.Yasir a.alkadhim** *for his valuable help. I would like to have the pleasure of thanking to my friends and colleagues who stood beside me from the beginning till I finished my work.*

Gratefully, I would like to present my deepest gratitude and love to my family who so ever encouraged me through my life, and to my dear husband that filled my life with love and support.

Abstract

This in vitro study was conducted to evaluate the effect of two staining drinks **(Tea and Pepsi cola)** on the color stability of four types of aesthetic archwires from four different companies. Total numbers of 48 strips “480 archwires” were prepared, each strip contains 10 aesthetic archwires were subjected to color change measurement and divided according to type of solution into two groups:

- **Group A**: 24 strips (12 strips were immersed in Tea and 12 strips were immersed in distilled water as control group)
- **Group B:** 24 strips (12 strips were immersed in Pepsi cola and 12 strips were immersed in distilled water as control group)

Each group was divided according to time of immersion into:

- Time 1 group: 4 strips were immersed for 1 week.
- Time 2 group: 4 strips were immersed for 2 weeks.
- Time 3 group: strips were immersed for 3 weeks
- Control group: 12 strips were immersed into distilled water for corresponding time as control.

Each subgroup contain one specimen from each company. The specimens were immersed into the solutions and incubated at 37°c for the required time then subjected to the color stability measurement by the computed spectrophotometer and the result was calculated according to Commission Internationale de l’Eclairage 1976 L*a*b’* color space system (translated as the International Commission on Illumination). The resulting data were statistically analyzed using Analysis of variance test **(ANOVA)** and least significance difference test **(LSD)**.

The result shows that both staining drinks (tea and Pepsi cola) caused color change in the aesthetic archwires in a variable degree, and the color change was increased with time ,the tea caused highly significant change on the aesthetic archwires which is higher than the effect of the Pepsi cola and the higher amount of color instability was found for the archwires from the Hubit company after immersion in tea which turns completely into yellow in color , while the least amount of color change was for the archwires from the Orthotechnolgy company after immersion in Pepsi cola.

List of contents

Chapter one: Review of literature

Chapter two: Material and Methods

Chapter three: Results

Chapter four: Discussion

Chapter five: Conclusions and Suggestions

List of Tables

List of Figures

List of Abbreviation

Abbr.	*Criteria*
Δ E*	Total color differences
Δ L*	Total L* coordinate differences
Δ a*	Total a* coordinate differences
Δ b*	Total b* coordinate differences
nm	Nanometer
$\int$	Mathematical integration.
C^o	Centigrade
λ	Wavelength
a*	the red/green coordinate,
A.W.	Archwires
ANOVA	Analysis of variance test
b*	the yellow/blue coordinate
C	Carbon
C*	the Chroma coordinate
CIE	Commission Internationale de l’Eclairage (translated as the International Commission on Illumination)
Co-Cr	Cobalt-chromium
Cr	Chromium
Cu	Copper
CuNiTi	Nickel Titanium Copper Chromium Alloys
CVD	Chemical Vapor Deposition
E	the modulus of elasticity
E λ	Standard illuminants
F2	Fluorescent illuminants
FDA	Food and Drug Administration
Fe	Iron
FRP	fiber reinforced plastic
H*	the hue angle, expressed in degrees

I D65	Incandescent Day light illuminants
L*	the lightness coordinate
LSD	least significance difference test
Max.	Maximum
Mg	Magnesium
mg	milligram
ml	Milliliter
Min	Minimum
NBS	National Bureau of Standards units
Ni	Nickel
NiTi	Nickel Titanium alloys
Ortho.t.	Orthotechnology company
PTFE	Polytetrafluoroethylene
PVD	Physical Vapor Deposition
QLF	Quantitative light-induced fluorescence
R λ	Reflection of object at a given wavelength
RF	Radiofrequency
RF-ICP	radiofrequency inductively coupled plasma
RGB	red, green and blue
SD	Standard Deviation
T1	Time 1 : the reading after immersion for 1 week
T2	Time 2: the reading after immersion for 2 weeks
T3	Time 3 : the reading after immersion for 3 weeks
Ti	Titanium
Ti-Molium	alpha-beta titanium alloy
Ti-Nb	nickel-free titanium niobium alloy
TiNb/Fa	Titanium Niobium Finishing Archwires
TiO_2	titanium oxide
TMA	Titanium Molybdenum Alloys
TPS	Thermal Plasma Spray
UV-VIS	Ultra violet –visible
x-, y- ,z-	three color-matching function

XYZ	tristimulus values X (red), Y (green) and Z (blue)
YS	yield strength
YS/E	(Spring back) the ratio of yield strength (YS) to the modulus of elasticity (E) of the material

Introduction

Esthetic of the patient, is one of main concerns during orthodontic treatment. There is a growing demand for esthetic appliances because most fixed orthodontic appliance components are metallic and silver in color, the demand for esthetic orthodontic appliances is increasing, and the development of materials that present an acceptable esthetics for the patients and an adequate clinical performance for clinicians is needed, this demand has led to the development of orthodontic appliances with acceptable esthetics both for patients and clinicians **(Elayyan *et al.*, 2008; Kaphoor and Sundareswaran, 2012)**

The problem has been partially solved by the introduction of esthetic brackets made of ceramic or composite, which are becoming more popular. However, most archwires are still made of metal such as stainless steel and nickel-titanium. A number of alternatives have been explored to create an esthetic archwire that would allow efficient orthodontic treatment from the labial aspect (**Russell, 2005; Burstone, 2011)**.

Metallic archwires coated with tooth-colored resin materials, such as synthetic fluorine-containing resin or epoxy resin composed mainly of poly-tetra-fluoro-ethylene, are currently the existing solution to this esthetic problem, ideally, the color of esthetic archwires should match that of natural teeth and esthetic brackets **(Bolt *et al*., 1994; Ramadan, 2003; Li y, 2009).**

The color stability of esthetic archwires during orthodontic treatment is clinically important, any staining or discoloration or change in esthetic of patient will affect the cooperation and acceptance to his treatment, color instability of these wires and exposure of the underlying metal is also often reported. It has been found that 25% of coating is lost in 33 days intraorally, therefore, the wire becomes aesthetically degraded **(Lim *et al*., 1994; Elayyan *et al*., 2008)**. Coating improves esthetics but has some disadvantages, the color tends to change with time; **Proffit in (2000)** describes the coat as “un-durable”, like other esthetic orthodontic products, there are internal and external causes for the discoloration of esthetic archwires. External discoloration can be caused by food dyes and colored mouth rinses, the type of coating material and its surface roughness play decisive roles in the extent of the discoloration caused by diverse substances. The amount of color change can be influenced by a number of factors, including oral hygiene and water absorption **(Faltermeier *et al*., 2008).** Therefore, and because there is no previous Iraqi study about the color stability of the aesthetic archwires; this an in vitro study, is done to evaluate the color stability of different type of aesthetic archwires after immersion in two types of staining drinks which are tea and Pepsi cola.

Aims of the study

- To evaluate the color stability of different aesthetic archwires from four different companies which are: (Dany company, G&H Company, Hubit Company and Orthotechnology Company) after immersion into two types of staining drinks which are tea and Pepsi cola.
- To compare between the effect of tea and the effect of Pepsi cola on the color stability of these different aesthetic archwires.
- To find the effect of immersion time in these staining drinks on the color stability of these different aesthetic archwires.

CHAPTER ONE

Review of Literature

1.1. Fixed Orthodontic Appliance:

Orthodontic appliances can be defined as devices, which create and/or transmit forces to individual teeth/a group of teeth and/or maxillofacial skeletal units so as to bring about changes within the bone with or/without tooth movement which will help to achieve the treatment goals of functional efficiency, structural balance and esthetic harmony **(Singh, 2007).**

Or it can be define as the type of appliances that the patient cannot removed it from his / her mouth, because it is fixed to the teeth by cementation or composite **(AL-Mulla, 2009).**

According to **Foster (1990)**, fixed appliances form the second major division of orthodontic appliance systems. They have certain important advantages, as well as certain disadvantages, when compared with removable appliances.

Esthetic of the patient, is one of main concerns during orthodontic treatment. There is a growing demand for esthetic appliances, but most fixed orthodontic appliance components are metallic and silver in color (**Elayyan *et al.,* 2008).**

As the number of adults seeking orthodontic treatment increased, orthodontists felt the need to provide their patients with more esthetically "appealing" appliances, this perceived need motivated manufacturers to provide acceptable esthetic brackets, including the non-metallic brackets **(Bishara and Fehr, 1997)**, so this problem has been partially solved by the introduction of esthetic brackets made of ceramic or composite, which are becoming more popular **(Russell, 2005).**

However, most archwires are still made of metal such as stainless steel and nickel-titanium. A number of alternatives have been explored to create an esthetic archwire that would allow efficient orthodontic treatment from the labial aspect **(Burstone, 2011).**

1.2. Orthodontic attachments:

The orthodontic attachments are these components of fixed appliance to which the force component can be applied **(Reynolds, 1979; Demuth, 1981; Foster, 1985).**

According to **AL-Mulla (2009)** the orthodontic attachments consist of:

- Brackets, which are usually fitted on the anchor teeth and on the teeth to be moved.
- Tubes, which are usually fitted on the molars in the arch.
- Buttons and cleats: can also be added to the teeth as an attachment of auxiliary forces

.

1.2.1. Brackets:

The bracket is defined as a part of the fixed appliance that projects horizontally to support auxiliaries and is open on one side usually in the vertical or horizontal in which the arch wire is fit into it **(Singh, 2007).** Orthodontic brackets bonded to enamel provide the means to transfer the force applied by the activated archwire to the tooth (**Brantley and Eliades, 2001).**

The brackets must be able to deliver orthodontic forces and masticatory loads, have esthetic appearance and result in minimal damage to the hard and soft tissues during application, service and removal at the end of treatment **(Foster, 1985)**, they could be classified according to the bracket material into fallowing:

1.2.1.1. Metal brackets:

a. Stainless steel brackets:

The use of metal brackets with retentive bases was first reported by **Mitchell** in **1967**. Although not as esthetically pleasing as plastic, ceramic or composite brackets, the stainless steel brackets were an esthetic improvement over previously used band as shown in **figure 1-1 (Graber and Swain, 1991; Proffit *et al* ., 2007) .**

Corrosion of stainless steel bracket bases is a problem, which could result in enamel staining **(Maijer and Smith, 1982)**. Therefore these brackets were made from corrosion resistant stainless steel containing Nickel (Ni), Chromium (Cr), and various proportion of Magnesium (Mg), Copper(Cu), Titanium(Ti), Carbon(C) and Iron(Fe) **(Craig and Ward, 1997; Gürsoy *et al*., 2005) .**
Corrosion resistance could be increased by incorporating higher proportions of Cr, Ni, Molybdenum and Ti, and lower amount of Sulfur and Carbon **(Huang *et al*., 2001).**

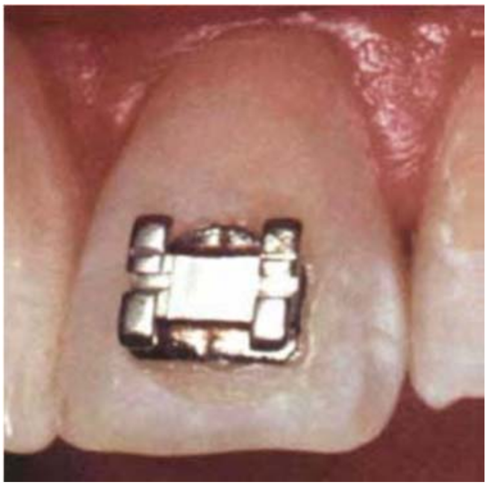

Figure 1-1: stainless steel bracket

(Proffit et al., 2013)

b. Nickel free, Cobalt Chrome alloy brackets:

Most alloys used in orthodontics contain the potentially toxic Nickel that might cause sensitivity and allergic reaction for the patient **(Craig and Ward, 1997; Eliades and Athanasiou, 2002).**

Saliva is an active environment of organic constituents, ions and non-electrolytes that constantly wash against brackets. Galvanic differences between saliva and metal triggered electrochemical reactions, which could lead to corrosion. This would cause dissolution of Nickel and Chromium, followed by leaching of heavy metals from stainless steel **(Hamula *et al*., 1996; Kim and Johnson, 1999);** Nickel containing alloys can undergo corrosion with the release of metal ions, because they remain in the oral cavity and subjected to the oral environment's physical properties (chemical and microbiological properties), that stimulate the dissolution of metals. **(Setcos *et al*., 2006; Freitas *et al*., 2008).**

The Cobalt Chrome (which had been successfully used for many years in prosthetics) could be used for manufacturing brackets to improve the biocompatibility **(Dentaurum catalogue, 2009).**

c. Titanium brackets:

Titanium (Ti) alloys are highly corrosion resistant, well tolerated by the human body, and almost as strong but not as stiff as stainless steel **(Graber,2000)** ; the introduction of new, pure titanium bracket **(Rematitan)** that was competitive in cost to stainless steel bracket, had been solved the problems of corrosion and Nickel sensitivity as shown in **figure 1-2** . It was one piece construction, required no brazing layer, and thus it is solder and Nickel free. Titanium brackets are made from a pure, medical grade Titanium that had greater strength, lower density and lower modulus of elasticity. Also, Titanium had low thermal conductivity and it imparted none of the metallic taste of stainless steel brackets **(Hamula *et al*., 1996; Craig and Ward, 1997);** Titanium brackets are single piece cast brackets.

They are ideal for use in patients with nickel hypersensitivity. Titanium brackets are more expensive than stainless steel brackets **(Singh, 2007)**.

In addition to its hypoallergenic properties, titanium brackets and tubes seem to reduce the failure rate in bonding, perhaps because the material is more "wettable" and the bonding materials adhere better to the retention pad, perhaps because titanium is more resilient than steel and absorbs impacts better **(Proffit *et al.*, 2013).**

Figure 1-2: Rematitan Bracket (Titanium Bracket)

(Abdulameer, 2008)

1.2.1.2. Non-metal brackets:

a. Plastic Brackets:

During the early 1970, plastic brackets were marketed as esthetic alternatives to metal brackets. They have the advantages of being tooth colored and non-allergenic **(Proffit *et al.,* 2007)** Plastic brackets to be bonded directly to enamel were initially made of polycarbonate and plastic molding powder (Plexiglas) **(Bishara and Fehr, 1997; AL-Mulla, 2009).**

The polycarbonate brackets quickly lost favor because of discoloration and slot distortion caused by water absorption **(Newman, 1969; Reynolds, 1975; Hershey, 1987; Bishara and Trulove, 1990; Britton *et al.*, 1990; Chaconas *et al.*, 1990)**, this led manufacturers to modify the plastic brackets by reinforcing the slots with metal and ceramic fillers **(Winchester, 1991; Brantley and Eliades, 2001; Faltermeier *et al.*, 2006)**, and would prevent the brackets from staining and improve the strength of polycarbonate brackets **(Faltermeier *et al.*, 2006; Proffit *et al.*, 2013)**, and that the metal slot would prevent distortion during torque force application and reduce bracket-wire friction **(Feldner *et al.*, 1994; Bazakidou *et al.*, 1997; Sadat-Khonsari *et al.*, 2004; Proffit *et al.*, 2013) .**

But even with this modification, plastic brackets are useful only when complex tooth movements are not required. **(Proffit *et al.*, 2013).**

Fiber glass reinforced brackets do not show any tendency for fracture like ceramic bracket and do not pose any hazard in debonding **(figure 1-3) (Brantley and Eliades, 2001)**,they can be debonded like metal brackets. No enamel damage unlike ceramic brackets has been encountered during their debonding. Also the disadvantages seen with these brackets are-they tend to get worn off if in contact with opposing teeth and they cannot be recycled satisfactorily **(Singh, 2007).**

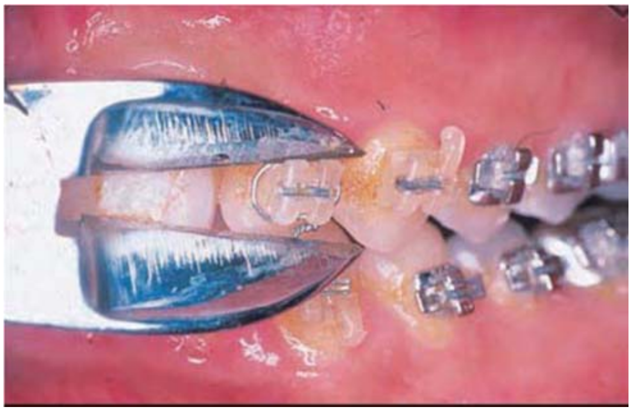

Figure 1-3: Plastic Bracket Exhibit Bonding Distortion during Deboning (Brantley and Eliades, 2001)

b. Ceramic Brackets:

Ceramic brackets became quite popular in the 1980s because of their improved esthetics as a more esthetic alternative to the traditional stainless steel brackets, but problems related to frictional resistance to sliding have limited their use **(Bordeaux *et al*., 1994; Brantley and Eliades, 2001; Proffit *et al*., 2013)**; Ceramic brackets are more esthetic than metal brackets, and unlike plastic brackets, they resist staining and discoloration **(Meguro *et al.,* 2006)**; as shown in **figure 1-4 (Proffit *et al*., 2007).**

Ceramic brackets largely overcome the esthetic limitations of plastic brackets in that they are quite durable and resist staining. In addition, they can be custom-molded for individual teeth and are dimensionally stable, so that the precise bracket angulations and slots of the straight-wire appliance can be incorporated; Ceramic brackets were received enthusiastically and immediately achieved widespread use, but problems with fractures of brackets, friction within bracket slots, wear on teeth contacting a bracket, and enamel damage from bracket removal soon became apparent. Ceramics are a form of glass, and like glass, ceramic brackets tend to be brittle **(Proffit *et al.,* 2013).**

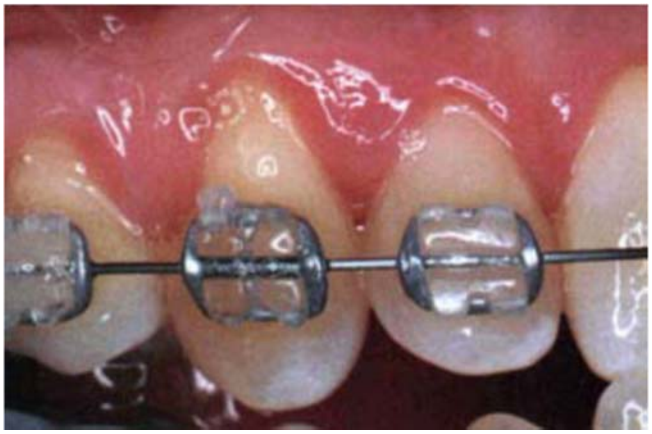

Figure 1-4 Ceramic twin brackets (Proffit *et al.,* 2007)

c. Composite Brackets :

The term composite material refers to three dimensional combinations of at least two chemically different materials with distinct interface separating the components **(Matasa, 2005)**.

Composite plastic brackets will begin to be used in orthodontics within the next few years. They have the advantages of being tooth colored and non-allergenic, and at least in theory, should have surface properties that would not be as troublesome as ceramics.As with composite plastic wires, their fabrication is difficult and their advantages relative to metal may not be worth the additional expense, and since the composite plastics can be almost any color, a better appearance is likely to be an additional benefit **(Proffit *et al.*, 2013)**; as shown in **figure 1-5 (Graber and Matasa, 2005)** .

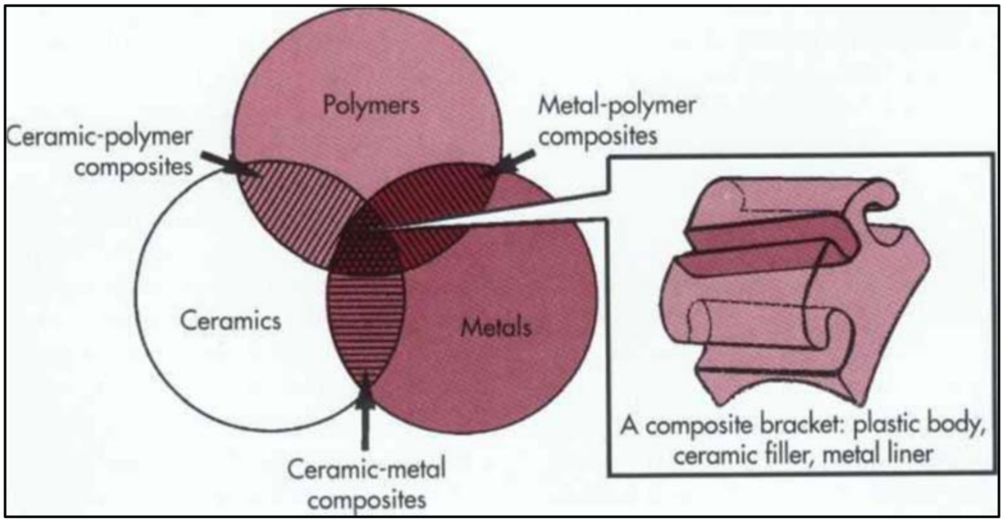

Figure 1-5: Modern composite bracket made of metal, polymer, and ceramic (Graber and Matasa, 2005).

Ceramic-reinforced composite brackets without a metal slot insert have been shown to have fairly low frictional characteristics compared with ceramic and metal brackets **(Bazakidou *et al.,* 1997);** Hence the newly introduced ceramic-reinforced plastic brackets are suitable for clinical use because they are color stable, have lower friction,"' and have the structural integrity to transmit orthodontic forces without distorting **(Bishara, 2000).**

Composite bracket was manufactured from Polyurethanes and polyester which was reinforced with powders or fibers, customized both stiffness and strength. **(Jancar and Dibenedetto, 1993)**.

1.2.2. Bands:

These are rings encircling the tooth to which buccal, and as required, lingual attachments are soldered or welded; as shown in **figure1-6 (Proffit *et al.*, 2013)**. Prior to the introduction of the acid -etch technique, bands were the only means of attaching a bracket to a tooth. With the development of modern bonding techniques, directly bonded attachments became popular **(Mitchel *et al.,* 2007)**. Until the 1980s, the only practical way to place a fixed attachment was to put it on a band that could be cemented to a tooth **(Proffit *et al.,* 2013).**

Orthodontic bands are made exclusively from stainless steel material. The buccal attachments on the molar bands vary according to the number of tubes and hooks incorporated in the design. These may be single, double, or triple tubes, depending on the practitioner's philosophy and requirements. Varieties of lingual attachments are also available and can be preselected by the clinician. These attachments are generally casted separately and then welded to the preformed bands **(Bishara, 2001)**, All bands have lingual cleats attached. Lingual cleats increase versatility and are especially necessary to correct band control rotations **(Graber *et al.,* 2012)**.

Figure 1-6: Molar Band (Proffit et al., 2013)

1.2.3. Buccal Tubes:

Buccal tubes are horizontal hollow tubes, round, rectangular or oval in shape; they are generally used on molars and help provide better three dimensional controls of these anchor teeth as shown in **figure 1-7(Proffit *et al.*, 2007)**.

Tubes which are usually fitted in the last molars in the arch may be round or rectangular section, larger tuber is used to take extra-oral arches. These tubes usually pre-welded on molar band and can be cemented on molar teeth **(Bishara, 2001; Singh, 2007; Al-Mulla, 2009).**

Figure 1-7: bonded buccal tube (Proffit *et al.,* 2007)

1.2.4. Buttons and cleats:

These are accessory attachments other than brackets and tubes which are placed on the lingual aspect of teeth (bonded) or bands (welded); **figure 1-8 (Singh, 2007)**, so that cross elastics could be worn **(Proffit *et al.*, 2013)** ;Buttons and cleats can also be bonded to the teeth as an attachment of auxiliary forces **(Al-Mulla, 2009)** .

For impacted or un-erupted tooth a button or hook is better than standard bracket because it is smaller. It is possible to bond a button to a rotated tooth so that a rubber band can be used to rotate it **(Proffit *et al.*, 2013).**

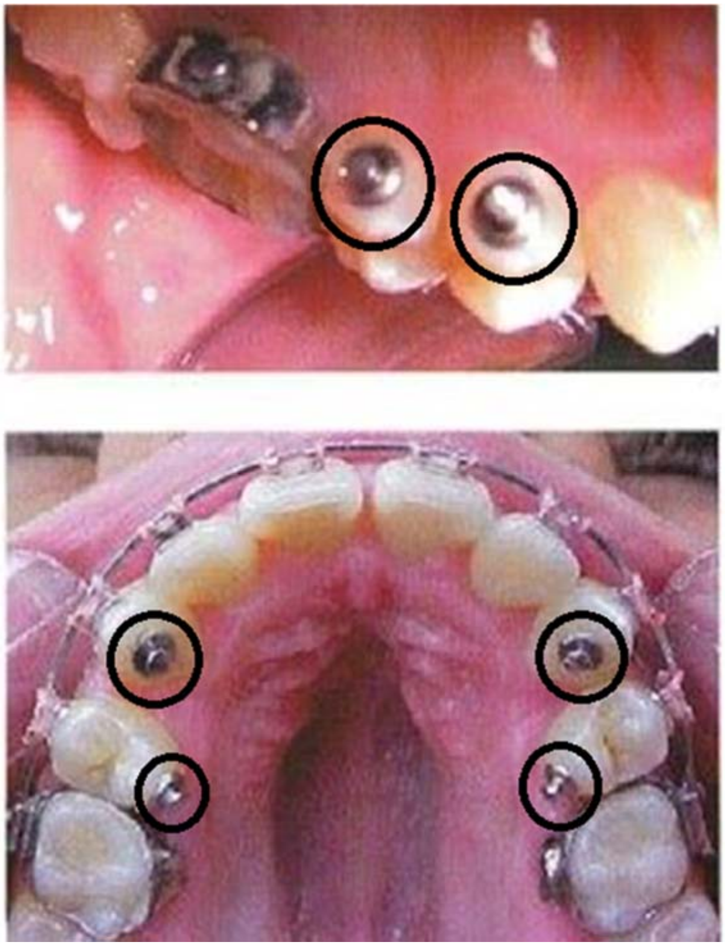

Figure 1-8: lingually bonded buttons (Esequiel *et al,* 2007)

1.3. Archwires:

The archwire is that part of a fixed appliance, which generate the biomechanical forces communicated through brackets for tooth movement **(Brantley and Eliades, 2001)**.Orthodontic wire are formed into various configurations or appliances to apply forces to teeth and move them into a more desirable alignment **(Anusavice, 1996)**.

Archwires are the base wires, which are engaged in brackets of the various appliance systems. These are used to provide a proper arch form and / or provide a stable base to which the auxiliaries can be attached to generate the tooth moving forces **(Singh, 2007)**.

The orthodontic archwire is a vital component of the fixed orthodontic appliance. An ideal archwire should be able to move teeth with a light, continuous force. This force should be designed to minimize patient discomfort, tissue hyalinization, and root resorption. When a force is applied, the archwire should behave elastically over a period of weeks to months **(Gurgel *et al.*, 2001)**.

1.3.1. Wire Characteristics of Clinical Relevance:

There are different characteristics considered desirable for a wire's good behavior depending on the clinical case (**Wilcock, 1988; Kapila and Sachdeva, 1989 ; Kusy ,1997 ; Mitchell ,2001 ; Singh,2007) figure 1-9** ; The physical properties of an archwire material which are of interest to the orthodontist are as follows:

- **Spring back**: This is the ability of a wire to return to its original shape after a force is applied. High values of spring back mean that it is possible to tie in a displaced tooth without permanent distortion **(Mitchell, 2001).**

  Spring back is also referred to as maximum elastic deflection or working range. Spring back is related to the ratio of yield strength (YS) to the modulus of elasticity (E) of the material (YS/E), a large range of activation enables the clinician to achieve larger activations resulting in the wires increased working time **(Ingram *et al.*, 1986; Zufall and Kusy, 2000; Singh, 2007).**

- **Stiffness:** The amount of force required to deflect or bend a wire; or is the amount of force required per unit of activation **(Jay *et al.,* 1997; Mitchell, 2001)**; the greater the diameter of an archwire the greater the stiffness. This is the force magnitude delivered by an appliance and is proportional to the modulus of elasticity (E). Low stiffness leads to an ability to apply lower forces, a more constant force to be delivered over time and greater ease and accuracy in applying a given force **(Singh, 2007).**
- **Formability:** This is the ease with which a wire can be bent to the desired shape, high formability provides the ability to bend a wire into desired configurations such as loops, coils .etc. without fracturing the wire **(Burstone and Goldberg, 1980 ;Proffit and Fields, 2000; Mitchell , 2001; Singh,2007)**

- **Resilience:** This is the stored energy available after deflection of an archwire without permanent deformation; It is represented by the area under the line describing elastic deformation of the wire **(Kusy, 1997; Mitchell , 2001; Singh,2007)**

- **Biocompatibility:** includes resistance to corrosion and tissue tolerance to wire elements. Ideally, the wire should neither favor nor be a substrate for developing microorganisms and allergies (**Kapila and Sachdeva, 1989**).

- **Joinability:** This is whether the material can be soldered or welded. **(Mitchell,2001)**; Welding of attachments to the arch wire for proper force delivery has fascinated the clinicians by its ease of force application and this required arch wire alloy with superior weld characteristic **(Krishnan and Kumar, 2004).**
- **Frictional characteristics:** Friction is the resistance to movement of two or more contacting bodies that occurs tangent to the plane of contact (**kusy, 2005)**; Low friction major property when attempting to relatively move a tooth/bracket along a wire **(Angolkar *et al.,* 1990; Kusy and O'Grady, 2000)**. If tooth movement is to proceed quickly a wire with low surface friction is preferable. The preferred wire material for moving teeth relative to the wire should produce the least amount of friction at the bracket/wire interface. Excessive friction can result in loss of anchorage or binding accompanied by little or no tooth movement **(Singh, 2007).**
- **Good Strength**: Strength is a measure of how strong force the wire will take before it permanently deforms (**Creekmore, 1976)**.

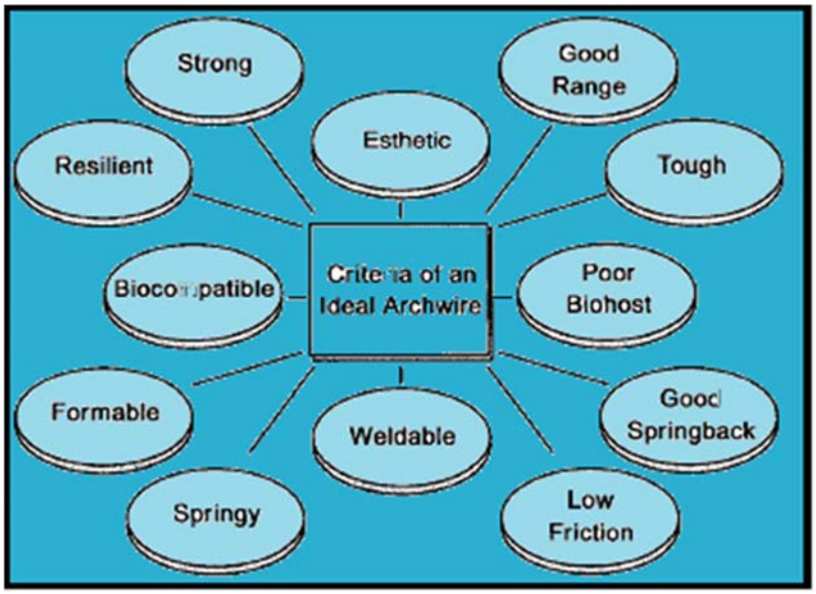

Figure 1-9: Criteria of an ideal arch wire (Kusy, 1997)

1.3.2. Types of Archwire:

Orthodontic wires can be classified according to materials based on material constituent, cross section, diameter of the arch wire and microstructural arrangement **(Singh, 2007)**

Also archwires may be classified by **(Birnie, 2005)**:

- **Material**: into stainless steel, Elgiloy, titanium alloys, glass, polymers .
- **Morphology**: into round, rectangular, single, multistrand or braided.
- **Coated Or Non- Coated**: into ion implantation, spray coating, sleeving .
- **Composite**: into

a. Made of more than one morphology (e.g. wonder wire).

b. Made of one or more materials with a mechanical join or material .

c. Having different properties in different sections of the archwire (e.g.) GAC Bioforce, and Forestadent Triple Force).

1.3.3. Orthodontic Archwire Materials:

Ireland and McDonald in **2003** reported that there are several types of arch wire materials available to the orthodontist, these are:

1.3.3.1. Precious Metal Alloys:

In the first half of the 20th century, precious metal alloys were used routinely for orthodontic purposes, primarily because nothing else would tolerate intraoral conditions. Gold itself is too soft for nearly all dental purposes, but alloys, which often included platinum and palladium along with gold and copper, could be useful orthodontically. These alloys could be heat treated to harden them and then provide a light gentle pressure **(Mills, 1987; Proffit *et al.*, 2013).**

Precious metal alloys were inert, biocompatible and environmentally stable. The other materials available were unable to tolerate the extracting oral conditions **(Singh, 2007)**. Currently, the only considerable advantage to gold is the ease of fabricating cast appliances, such as custom-fit bonding pads used with fixed lingual appliances **(Proffit *et al.*, 2013).**

Although these noble-metal wires have minimal use currently because of their much greater cost compared to popular base metal wires **(Brantley and Eliades, 2001).**

1.3.3.2. Stainless Steel Alloys:

By the **1950s** stainless steel alloy were used for most orthodontics wires, stainless steel wires remain popular because of their favorable combination of low cost and excellent formability **(Brantley and Eliades, 2001)**.

Family of steels that contain more than 12% chromium owes its success in the manufacture of instruments and attachments to combined high mechanical strength, acceptable appearance, and chemical resistance. Stainless steel entered dentistry in **1919**; Angle used it in his last year **(1930)** as ligature wire.

By **1937** the value of stainless steel as an orthodontic material had been confirmed, the stainless steels used early in orthodontics were highly resistant to corrosion because of their low carbon and sulfur content and high chromium and nickel content. Chromium protects the steel with an impermeable, corrosion-resistant layer of its oxide **(Graber *et al.*, 2005)**. These properties of steel wires can be controlled over a reasonably wide range by varying the amount of cold working and annealing during manufacture. Steel is softened by annealing and hardened by cold working **(Proffit *et al.*, 2013)**.

Stainless steel replaced precious metal in orthodontics because of considerably better strength and springiness with equivalent corrosion resistance **(Proffit *et al.*, 2007).**

The stainless steel alloys used for orthodontic arch wires are of the (18-8) austenitic type, containing approximately 18% chromium and 8% nickel; the chromium in the stainless steel forms a thin, adherent passivation oxide layer that provides corrosion resistance by blocking the diffusion of oxygen to the underlying bulk alloy. Approximately 12-13 % chromium is required to impart the necessary corrosion resistance to these alloys (**Brantley and Eliades, 2001**).

Types of stainless steel:

1) Martensitic Stainless Steels:

Starting in the 1970s, in addition to carbon, other elements were added to stainless steels to stress their microstructure and thereby increase tensile strength, but less corrosion-resistant alloys were the result. This may contain 12 to 13 % chromium, a small amount of carbon. These alloys can be hardened by heat treatment (**McCabe, 1985**).

Such steels should be used only for short contacts with the oral environment. Because of their stressed, these steels are used primarily for instruments that require sharp or wear-resistant edges **(Graber et al, 2005)**; because of their high strength and hardness, martenesitic stainless steel is used for surgical and cutting instruments (**Anusavice, 1996).**

This alloy can be hardened by heat treatment. Strength increases and ductility decreases with increasing hardness **(Shrier, 1979)**.

2) Ferrite Non–Hardenable Stainless Steels:

The name ferritic steel derives from the fact that the microstructure of these steels is the same as that of iron at room temperature. The difference is that in ferritic steel, chromium is substituted for some of the iron atoms **(Graber *et al.*, 2005)**. They cannot be hardened by heat treatment; it has low strength, good corrosion resistance and low cost. The composition of this type includes chromium (11.5–27%), nickel (0%), and carbon (0-2%). This type of alloy finds little application in dentistry. At room temperature it has a body-centered cubic structure **(Craig and Powers, 2002).**

The modern "super ferritics," which belong to this category, contain 19% to 30% chromium and are used in several nickel-free brackets. Highly resistant to chlorides, these alloys contain small amounts of aluminum and molybdenum and very little carbon **(Graber *et al.*, 2005)**.

3) Austenitic Stainless Steels:

Structurally this steel is solid solution and cannot be hardened by heat treatment. Like the ferritic steels, they are hardenable by cold working. The composition of this alloy basically include, chromium (16 – 26%), nickel (7 – 22%), carbon (0.25% max), and iron (72%) **(Matasa, 2000)**.

Austenitic steels are used to make most attachments. Structurally these steels are solid solutions, which offer better corrosion resistance. The face centered cubic crystal structure renders these steels non ferromagnetic, it is unstable at low temperatures where it tends to run in to another structure known as ferrite. If "austenitizing" elements (Nickel, Manganese, and Nitrogen) are added, the highly corrosion-resistant solid solution phase can be preserved even at room temperature. If these elements are absent, these steels, even with high chromium content, are ferritic at room temperature. The balance of austenite ferrite-martensite often is unstable, because even the austenitic steels that have the correct amount of such elements and are paramagnetic may turn into ferrite or martensite (which are ferromagnetic) when subjected to extensive cold work **(Graber *et al.*, 2005)**

If the austenite cooled rapidly (quenched), it will end with body centered tetragonal structure called martensitic phase, at martensitic form this metal can be hardened by heat treatment, while austenite variety only hardens by cold work **(Fontana and Greene,1967)**.

Austenitic stainless steel has a very wide applications and is used in orthodontic wires **(Noort, 2002)**; it is the most corrosive resistant of stainless steel. It has the following Advantages (**Anusavice, 1996)** :

- Corrosion and tarnish resistance.
- Ductile (can undergo cold – working without fracture)

- Weldable and formable.
- Good strength

While the disadvantages of this wires according to **Mills, 1987** are:

- Difficulty in soldering.
- Cannot be hardened by tempering.
- Annealing during welding or soldering

1.3.3.3. Cobalt-Chromium Alloys:

Cobalt-chromium (Co-Cr) orthodontic wire alloy (Elgiloy) was developed during 1950s (**Graber *et al.*, 2000**) ; it was patented by the Elgin National Company (Lincoln, Neb) as the main spring of their analog watches with "the heart that never break" (**Kusy , 2001**).

These wires have properties similar to those of stainless steel but can be supplied in the softer and more formable state and then could be hardened by heat treatment. This process increases the strength of the wire significantly. This alloy is manufactured in four tempers, depending on the amounts of cold work: blue-soft and easy to bend, yellow-ductile, Green-semi-resilient and red-resilient. It is composed of (40%) cobalt, (20%) chrome, (15%) nickel, (15.4%) iron with small quantity of molybdenum, manganese, beryllium and others **(Singh, 2007)**.

Blue Elgiloy is the softest of the four wire tempers and can be easily bent with fingers or pliers. It is recommended for use when considerable bending, soldering or welding is required. Heat treatment of blue Elgiloy increases its resistance to deformation **(Kapilla and Sachdeva, 1989)**

Yellow Elgiloy is relatively ductile and more resilient than blue Elgiloy. It can also be bent with relative ease. Further increases in its resilience and spring performance can be achieved by heat treatment. Green Elgiloy is more resilient than yellow Elgiloy and can be shaped with pliers before heat treatment. The most resilient Elgiloy is marked red and provides high spring qualities, careful manipulation with pliers it recommended when using this wire because it withstands only minimal working. Heat treatments make a red Elgiloy wire extremely resilient, since this wire fractures easily after heat treatment, all adjustments should be made before precipitation hardening process **(Anusavice, 1996)**.

Elgiloy offers the potential for a significant change in the mechanical properties with the appropriate heat treatment. These wires have very good formability prior to heat treatment, which takes place once they are configured, thus increasing their stored energy and functionality **(Kusy, 1997)** With only a few exceptions, non-heat treated cobalt-chromium wires have a smaller spring-back than stainless steel wires of the same section **(Ingram *et al*., 1986)**.

The heat treatment increases strength significantly. After heat treatment, the softest Elgiloy becomes equivalent to regular stainless steel, while harder initial grades are equivalent to the “super” steels. This material had almost disappeared by the end of the twentieth century because of its additional cost relative to stainless steel and the extra step of heat treatment to obtain optimal properties **(Proffit *et al*., 2013)**.

1.3.3.4. Titanium Alloys:

Titanium system is well known as materials in orthopedic and odontology having chemical inertia, mechanical resistance, resistance to corrosion and biocompatibility **(Barbosa, 1992)**. Titanium alloys in orthodontic archwires were introduced in the early 1970s (**Kocadereli et al, 2000; Aderico et al, 2005).**

Titanium alloys are generally used as biomaterials, mainly as orthodontic wires, because of their interesting elasticity and shape memory capacity, which allow these materials to return to their original configurations after being submitted to a stress **(Gil *et al.,* 1996; Huang *et al.,* 2003; Schiff *et al.,* 2004; Cioffi *et al.,* 2005; Ferreira, 2008)**.

These properties that are not observed in the traditionally used stainless steel wires permit the orthodontist to apply continuous forces on the teeth, without causing discomfort to the patient. This is a positive aspect and stimulated the use of titanium alloys wires instead of stainless steel ones, mainly during the beginning of the treatment, when the teeth are more misaligned. Wrought alloys of titanium and nickel and of titanium and molybdenum are used for orthodontic wires; the term titanium is often used to include all types of pure and alloyed titanium **(Craig and Power, 2002; Chaturvedi, 2009).**

There are several types of titanium alloys which are used in orthodontics, these alloy are:

1. *Nickel Titanium*

This alloy was developed in **1971**, and marketed as 'Nitinol'. The name nitinol is an acronym derived from the elements which comprises the alloy (Nickel, titanium, nol-naval ordinance laboratory) **(Singh, 2007).**

The properties like shape memory and super elasticity of these wires have made them an indispensable material in contemporary orthodontic practice. These features are closely related to the phase transitions in its microstructure **(Kusy and Wilson, 1990)** ; Nickel titanium wires are commonly used during the aligning phase of orthodontic treatment, because they possessed a much lower elastic modules and higher elastic range than stainless steel wires, there by better able to provide `the light, continuous force over a large range of activations desired for orthodontic treatment **(Hazel *et al.*, 1984; Jia *et al.*, 1999; Pun and Berzins, 2008; Proffit *et al.*, 2013).**

Nickel titanium initial classification included three categories: super elastic, non superelastic, and true shape memory. This classification was confusing with respect to the meaning of the terms, and as a result, an alternative, structure-based classification was proposed by **Kusy** as (1) martensitic stabilized, which shows a stable martensitic structure, and thus no shape memory or superelasticity is expressed; (2) martensitic active, also termed thermoactive, in which an increase in the temperature leads to the transformation of the martensitic back to the austenitic structure; and (3) austenitic active, which demonstrates a pseudoelastic behavior, where the martensitic structure transformation of these alloys is stress induced, resulting from the activation of the wire **(Brantley, 2001; Graber *et al.*, 2012).**

2. *Nickel Titanium Copper Chromium Alloys (CuNiTi):*

CuNiTi was originally produced with four different austenitic transformation temperatures covering both pseudo elastic and thermo elastic archwires **(Birnie, 2005)**. The addition of copper decreases the difference between loading and unloading forces causing delivery of more constant forces for small activations. The addition of copper also increases surface smoothness making the surface roughness, more resistant to permanent deformation better spring back as compared to other NiTi alloys, and more constant forces are exerted over small activations. Copper content also plays an important role in controlling the transformation temperature of the alloy. The stress induced martensite is responsible for the superelastic characteristic of NiTi alloys **(Singh, 2007)**.

3. Titanium Molybdenum Alloys (TMA):

The use of beta-titanium alloys as orthodontic wires has been introduced in 1979 **(Goldberg and Burstone, 1979; Burstone and Goldberg, 1980)**. This Beta-titanium alloy composed of approximately 11.3 % molybdenum, 6.6 % zirconium and 4.3 % tin, with the balance titanium (approximately 77.8 %). The beta- titanium material was developed primarily for orthodontic use. It offers a highly desirable combination of strength and springiness (i.e., excellent resilience), as well as reasonably good formability. This makes it an excellent choice for auxiliary springs and for intermediate and finishing arch wires. The properties of beta-titanium are intermediate between stainless steel and martensite nickel titanium **(Proffit *et al.*, 2013).**

The Beta-titanium alloy is a metastable at room temperature due to presence of alloying elements such as molybdenum, vanadium and chromium **(Goldberg and Burstone, 1979)** and the final properties can be drastically altered by the thermal and mechanical processing used to produce the small diameter orthodontic wire **(Shastry and Goldberg, 1983)** ; A beta-titanium wire can be deflected almost twice as much as a similar stainless steel wire Moreover, it delivers half the amount of force applied compared to a stainless steel wire of similar section **(Goldberg and Burstone, 1979; Burstoe and Goldberg, 1980)**.

A new wire made of an alpha-beta titanium alloy called Ti-Molium has been recently launched, the wire's stiffness and other characteristics (such as elasticity and yield strength) are between the values set for stainless steel and beta-titanium wires **(Krishnan and Kumar, 2004).**

4. Titanium Niobium Finishing Archwires (TiNb/Fa):

This alloy has recently been used as a new finishing wire made from nickel-free titanium niobium alloy (Ti-Nb), it is soft and easy to form and has the same working range as stainless steel and its stiffness is 70 % lower than stainless steel and welding of Ti-Nb wire was found to be good **(Dalstra *et al.*, 2000)**.

The alloy has low spring back (equivalent to stainless steel) and is much less stiff than TMA. The alloy is useful when a highly formable wire with low forces in small activations is required **(Graber *et al.*, 2012).**

These wires are ideal as finishing wires as they can be bent more easily and still are able to maintain the low force levels required **(Singh, 2007)**.

1.3.4. Aesthetic Archwires:

The demand for esthetic orthodontic appliances is increasing, and the development of materials that present acceptable esthetics for the patients and an adequate clinical performance for clinicians is needed **(Elayyan *et al.*, 2010).**

A recent development in orthodontic wires included the use of composites. Up until now, an aesthetic wire accompanied with the required mechanical properties making it essentially useful for progress in orthodontics has not been found. The use of synthetic materials including matrixes reinforced with glass or others fibers is much promising (**Goldberg and Burstone, 1992; Zufall and Kusy, 2000**). In the wider scientific field of materials, polymers with shape memory have been produced and used in a variety of biomedical applications **(Lendlein *et al.*, 2005).** These materials may be a viable alternative to orthodontic wires currently used in the future (**Eliades, 2007**).

Two types of aesthetic wires available are metal-coated and fiber-reinforced wires. Of these two, those available for clinical use are the metal-coated ones, since fiber-reinforced ones are still in experimental stage.

1.3.4.1. fiber-reinforced wires:

Experimental type of aesthetic materials for orthodontic use referred to as self-reinforced polymer composites is also of particular interest. They are made of polyphenylene, which demonstrates time-dependent relaxation. Subsequently, their potential use in clinical practice will require the expert orthodontist to understand this behavior of wires (**Goldberg *et al.*, 2010**).

They are a new generation of materials that incorporates long fibers such as glass or carbon has been developed that possesses properties approaching those of metals. Wires or strips that are impregnated by the matrix and are unpolymerized are called “pre pregs.” These wires can be shaped passively to the shape of the arch and when light-cured harden to form a hard and stiff orthodontic component **(Daimaruya *et al*, 2001; Choi, 2009)**.

The first approach using a polyphenylene polymer (Primospire, Solvay Advanced Polymers, Alpharette, GA was pursuing by **Burstone in 1979**, this material extruded as round and rectangular cross section arches. It has properties similar to small dimension beta- titanium wires and formability similar to stainless steel wires. The second approach is being advocated by SimpliClear Braces (Biomers, Singapore), who fabricated archwires from a polymer resin matrix reinforced with glass fibers.

A specially modified methacrylate resin serves as the polymer matrix material. These wires are available in round and rectangular cross section, and can be paired with esthetic pre-torqued and pre-angulated brackets of the practitioner chose. Although this clear wire is not formable clinically, auxiliaries like rotating wedges or bracket repositioning can be used to treat simple cases without custom wires.

For more complex cases, a series of performed custom wires are made using either digital images from scans of dental casts or intraoral scans. This series is designed individually for every patient based on the treatment plan provided by the orthodontist prior to the onset of treatment. The wires are designed to sequentially and incrementally move teeth predetermined position. This clear wire also can be incorporated into retainer as the labial bow to provide an esthetic solution that allows settling with good stability **(Proffit *et al*., 2013)**.

1.3.4.2. Coated Orthodontic Archwire:

These wires are made of a combination of materials coated one on top of another. For each fiber/resin system, there is a heating or working range where the material can be formed or shaped without any degradation in its properties **(Singh, 2007).**

Metallic archwires coated with tooth-colored resin materials, such as synthetic fluorine-containing resin or epoxy resin composed mainly of polytetrafluoroethylene, are currently the existing solution to this esthetic problem **(Ramadan, 2003)**.

The coating is applied in a depository process that plates the base wire, and its thickness is approximately 0.002 inches, as reported by manufacturers. Thus, a strong adhesion is achieved between the coating and the wire **(Husmann *et al.*, 2002).**

Clear polymer archwires offer two potential advantages over stainless steel or titanium: better esthetics because the wire can be clear or the same color as the teeth, so that the wire become almost invisible when used with ceramic brackets and physical properties that equal or exceed those of metal archwires. Clear polymer archwires currently are being developed using two different approaches, a formable and a non-formable alternative **(Proffit *et al.*, 2013).**

1.3.4.1.1. Coating Techniques:

The application of coatings is one of the approaches that is available to modify the surface of materials. Various coating techniques and materials have been used with the objective of improving surface properties **(Santiago *et al.*, 2013)**; some problems with coatings have arisen, mainly the delamination or wear of the coating **(Park *et al.*, 2000)**

According to **Peláez-Vargas in 2000** the coating techniques included the thermal and chemical methods.

A. Thermal methods: include the following **(figure 1-10)**:

1. Thermal Plasma Spray (TPS):

This is a process in which finely ground metallic and non-metallic materials are deposited on a substrate in a molten or semi molten state. This technology is based on direct-current-arc or radiofrequency inductively coupled plasma (RF-ICP) discharge, which provides high temperature that, in turn, allow melting of any material **(Fridman, 2008).**

2. Chemical Vapor Deposition (CVD):

This technique involves the flowing of a precursor gas into a chamber that contains one or more heated objects to be coated. Some chemical reactions take place on and near the hot surfaces, which results in the deposition of a thin film on the surface **(Park and Sudarshan, 2001).**

3. Physical Vapor Deposition (PVD):

This process consists of atomic deposition procedures in which a material is vaporized from solid or liquid sources in the form of atoms or molecules and transported in the form of vapor through a vacuum or low-pressure gaseous (plasma) environment to a substrate, where it finally condenses. This technique is suitable for depositing films in the range of a few nanometers to thousands of nanometers, for multilayer coating, graded composition deposits, very thick deposits, and freestanding structures **(Mattox, 2010)**; this method includes:

- **Evaporation:** its Evaporation is the simplest physical vapor deposition method and has been proven useful for deposition of elemental films. This process is carried out in a vacuum system in which a material is heated to temperatures near its fusion or sublimation point **(Vásquez and Damborenea, 2001; Cao and Wang, 2011)**

- **Physical Sputtering:** This technique involves the vaporization of atoms or molecules from a solid surface by momentum transfer from bombarding energetic atomic-sized particles. These particles are ions of a gaseous material accelerated in an electric field **(Mattox, 2010; Cao and Wang, 2011)**. Physical sputtering can be divided into a number of methods, including radiofrequency (RF) magnetron sputtering and high-energy ionic scattering **(Peláez-Vargas, 2005).**

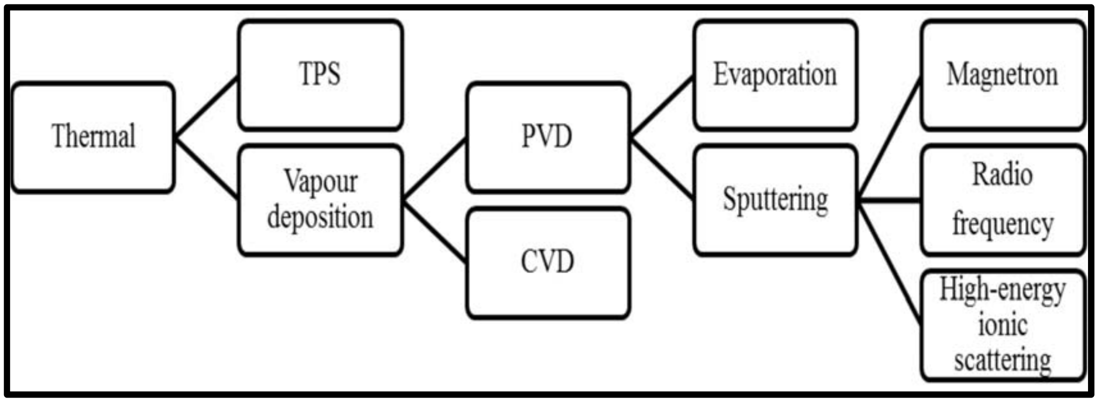

Figure 1-10: Classification of processes used for coating at the industrial level (Physical methods) (Peláez-Vargas, 2005)

B. Chemical Methods: which include **(figure 1-11):**

1. Electro deposition:

In this technique, the substrate to be coated is made the negative electrode or cathode in a cell that contains an electrolyte, which must allow the passage of an electrical current. The electrolyte is usually a solution in water of a salt of the metal to be deposited and is maintained at a controlled temperature. The electrical circuit is completed by the anode, which is generally made of the metal to be deposited, and is located a short distance from the cathode. When a direct, low voltage current is applied, positively-charged ions in the electrolyte move toward the cathode where they undergo conversion to metal atoms and deposit on the cathode **(Grainger and Blunt, 1998).**

Redlich *et al.* In 2008 used electro deposition to coat orthodontic archwires to reduce friction. The coating is based on a Ni film impregnated with inorganic fullerene-like nanospheres of tungsten disulphide. Their results showed a significant reduction in friction in coated vs. uncoated archwires.

2. Sol-Gel Method :

This process is a chemical method that allows the synthesis of glass, glass/ceramic and ceramic materials at temperatures much lower than other methods like CVD, PVD, or plasma spray and a variety of shapes, such as monoliths or nanospheres, among others, may be obtained **(Mackenzie and Bescher, 2000; Patil *et al.*, 2004; Peláez-Vargas, 2005).**

Chun *et al.*, in 2007 applied photo catalytic titanium oxide (TiO2) to stainless steel orthodontic wires using this method to evaluate its antibacterial and ant adherent properties. The results of their investigation showed that photo catalytic TiO2 may be used to prevent the development of dental plaque during orthodontic treatment.

While **Rendón *et al.*, in 2008** coated stainless steel orthodontic archwires with a glass using this method to evaluate friction between ceramic brackets and coated vs. uncoated archwires, since high friction coefficients are found between ceramic brackets and stainless steel archwires.

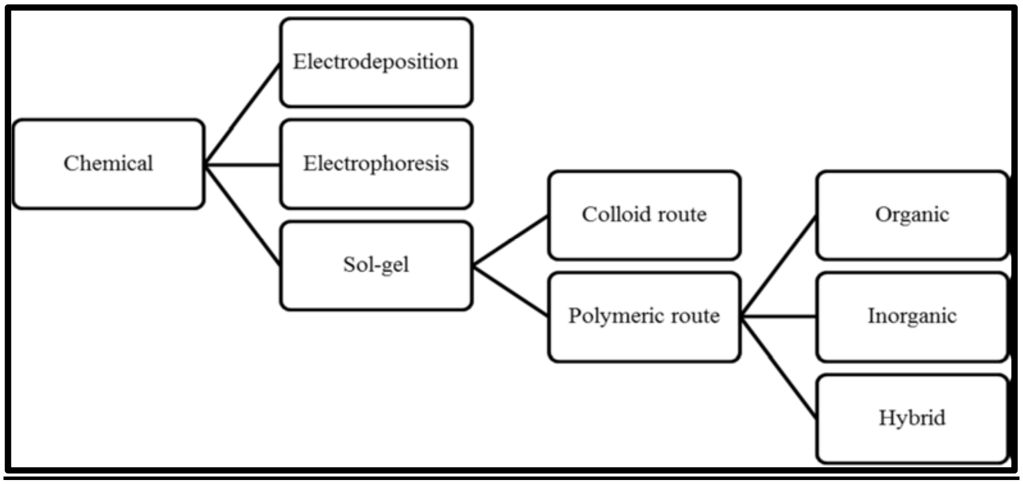

Figure 1-11: Classification of processes used for coating at the industrial level (Chemical methods) (Peláez-Vargas, 2005)

It was found that a reduction in friction was not observed when coated archwires were slid against monocrystalline sapphire ceramic brackets and the authors concluded that a glass coating using the sol-gel method is not suitable to reduce friction between stainless steel archwires and ceramic brackets **(Troczynski and Yang, 2001)**

1.3.4.1.2. Coating material:

Materials used for coating are synthetic fluoride resins, Teflon, or epoxy polytetrafluoroethylene resins, which is used to simulate tooth color **(Elayyan *et al.*, 2008; Ramadan, 2009; Elayyan *et al.*, 2010).** Coated metal archwires are nickel-titanium or stainless steel wires treated with a polytetrafluoroethylene (PTFE), epoxyresin, parylene-polymer, or less commonly palladium covering to impart an enamel hue; the so-called "white wires" **(Neal, 2013)**.

Coated nickel titanium arch wires are a new addition into the orthodontic inventory. In coating procedures, a substrate surface is usually refined by oxides, ethylene, teflon or with nitride ions to cause a permanent modification of the surface **(Husmann *et al*., 2002)**.

Many manufacturing companies have proposed various methods for obtaining and processing the NiTi archwires to decrease the negative effects and to meet patients' aesthetic needs. Thus, NiTi archwires were covered with Teflon based materials, composite resins, hydrogenated carbon or zirconium dioxide, which restricted corrosion, confined the release of nickel by (80%) and did not alter the mechanical properties of the archwires **(Husmann *et al.*, 2002; Ohgoe *et al*., 2007; Elayyan *et al*., 2008)** .The coated nickel titanium arch wire can remain austenitic well below oral temperature that allows it to take up greater force during activation, making the wire much springier and consistent in force delivery. Also it can maintained similar shape memory and super-elasticity properties after two months of intra-oral use, this can help in re-using the arch wire in different patients after sterilization. The black oxide coating can thus become beneficial in diversified oral environment **(Krishnan *et al*., 2012).**

1. Polytetrafluoroethylene (PTFE):

PTFE coating is applied to an orthodontic wire by thermal spraying, a process in which finely heated materials are sprayed in a molten condition onto a surface to form a coating

Thermal spraying of PTFE onto an orthodontic archwire entails **(Neal, 2013):**

- Surface treatment of the wire by sandblasting (50 -micron alumina) to support coating adhesion.
- “Masking” or covering with tape areas that are not be treated.
- Air-spraying atomized PTFE particles with clean compressed air to coat the wire.
- Baking in a chamber furnace to cure the coating onto the wire.
- Removal of the masking tape.

The PTFE layer adds a minimal thickness (.0008 to .001 inch) to the archwire. Recently, new vapor-parylene coated wires have been introduced, which use FDA-approved silver primer applied to the metal archwire to better secure a thinner aesthetic coating. **(Dany catalogue, 2011) (Figure 1-12)**

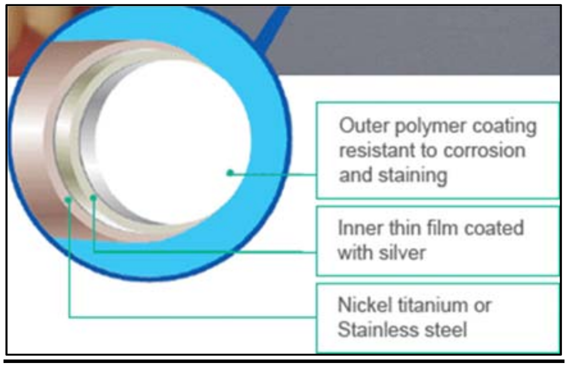

Figure 1-12: cross section of PTFE archwires (Dany catalogue, 2011)

2. Epoxy-resin:

Epoxy is a synthetic resin made by combining epoxide with another compound. Primarily recognized for its excellent adhesion, epoxies display a broad range of physical properties, such as chemical resistance, electrical insulation; and dimensional stability. They are widely used in orthodontic materials, including composite resins, molds, and polyurethane aligners. Epoxy-resin coating is applied to an orthodontic archwire by electrostatic coating, or E-coating. Electrostatic coating is a process that uses electrostatically charged particles to more efficiently coat a work piece **(figure 1-13)**. Electrostatic coating of epoxy resin onto an archwire entails:

- Applying a high-voltage electrostatic charge to the archwire,
- Applying an opposing electrostatic charge to the epoxy,
- Air-spraying atomized liquid epoxy particles to the wire, and
- Baking in a chamber furnace to cure the coating onto the wire.

Figure 1-13: epoxy coated archwire (ortho technology catalogue, 2014)

The epoxy coating does add a more significant thickness (.002 inch) to the archwire; therefore, a .0180-inch NiTi wire becomes .020-inch diameter with an

epoxy coating, or alternatively, the manufacturer may choose to use a smaller diameter wire to compensate for the thickness of the coating **(Neal, 2013)**
The challenge with coating metal archwires is the lack of available metal primer. Metal primer allows better cohesion between the archwire and coating. All current metal primers contain toxins, and these primers do not have FDA approval for use in the mouth. As such, the coating often separates from the archwire due to mastication and activation of digestive enzymes, research indicates that 25% of the epoxy coating is lost within the first month in vivo **(Elayyan *et al.*, 2008).**

1.3.4.3. Properties of aesthetic archwire:

The coating seems to initially lower bracket-wire friction **(Husmann *et al.*, 2002)**, however, surface roughness values soon increase in clinical use **(Elayyan *et al.*, 2008)** .The stiffness of these wires may be determined when manufactured without changing the wire's dimensions by changing fiber geometry and/or the ratios of fiber and matrix materials and properly polymerising them (**Imai *et al.*, 1998; Zufall and Kusy, 2000b**).

Coated wires deliver lower forces when loaded and unloaded compared to non-coated wires of the same nominal diameter , this finding, even though expected due to coating thickness, a slightly lower section wire is used, should be taken into account since a large number of orthodontics use wire diameter as their guide in certain clinical cases **(Elayyan *et al.*, 2010).** Stiffness for the Teflon coated stainless steel archwire was found to be higher than stainless steel wire **(Lim et al., 1994)**, and also showed that Teflon coating prevent the corrosion of the wire **(Neumann *et al.*, 2002).**

A study by **Imai *et al.*, in 1998** showed that the fiber reinforced plastic (FRP) wires possess enough good esthetically in their external appearance and are composed of biocompatible materials.

1.3.5. The color stability:

The color stability of esthetic archwires during orthodontic treatment is clinically important. Ideally, the color of esthetic wires should match that of teeth and esthetic brackets. But the colors of natural teeth differs according to color measurement protocols used and by race, age, and gender **(Bolt *etal.*, 1994).**

Silva *et al.* in 2013 stated that all esthetic archwires assessed in their study showed noticeable color changes after 21 days in staining solutions. They are prone to chewing forces or the enzymatic activity of the oral cavity within three weeks of use in vivo **(Kusy, 1997)**.

Color instability of these wires and exposure of the underlying metal is also often reported **(Lim *et al.*, 1994)**. It has been found that 25% of coating is lost in 33 days intraorally, therefore, the wire becomes aesthetically degraded **(Elayyan *et al.*, 2008)**.

1.3.6. Factor affecting staining of aesthetic archwires:

A. Saliva:

Saliva is a mixture of water, proteins, electrolytes and mineral elements, **(Fakhoury and Peraldi, 1996)**. Extrinsic discoloration may be caused by retention of colored substances in bacterial plaque and/or the acquired pellicle or by chemical alterations of these organic integuments **(Eriksen and Nordbo, 1978)**.

The acquired pellicle is formed by a selective adsorption of glycoproteins from saliva; in the mouth this process started immediately after cleansing and slowed down after 60-90 minutes **(Sonju, 1975)**.

Prayitno et al. (1979) found that acrylic specimens treated with saliva demonstrated increasing in staining and this lead them to suggest that there was an increased uptake of chlorhexidine and components of tea on to such specimens. This in vitro study indicated that in the mouth, pellicle derived from salivary glycoprotein would tend to encourage stain formation.

B. Diet:

Diet includes hard and soft food, There is a big role of diet due to natural food stains (concentrated tomato paste, grape juice, coffee-tea infusion, and orange juice) **(Pipko and El-Sadeek, 1972)** The solution that induced more staining was concentrated coffee-tea infusion, then concentrated grape juice solution, then concentrated tomato paste solution, and the least stain was induced by concentrated orange juice solution. Coffee is also a staining beverage and thought as analogous to tea in time of consumption, the research into color measurement for the two beverages had showed slightly different emphasis **(Francis and Clydesdale, 1975; Gross and Moser, 1977)**.

C. Smoking :

Smoking cigarette is considered as one of the causes of staining of acrylic resin **(Addy et al., 1979)**.

D. Mouth washes (Chlorhexidine) :

After 20 years of use by the dental profession, chlorhexidine is recognized as the gold standard against which other anti-plaque and gingivitis agents are measured **(Jones, 2000)**.

However, the side effect of extrinsic staining which results from chlorhexidine use remains the single most confounding limitation to its long-term use and has been the topic of considerable discourse and study **(Terri and Tillis, 1999)**.

Explanations of the staining mechanism have been postulated. It has been suggested that the staining results from compounds which are products of a series of rearrangement reactions between sugars and amino acids. Also seen in the browning of foods high in carbohydrates and sugars, such as apples and potatoes. The stain mechanism has also been described as a result of a local precipitation reaction between tooth bound chlorhexidine and chromogens found within foodstuffs and beverages **(Jones, 2000)**.

1.4. Assessment of color:

The color is influenced by observer variables, object variables and light source variables; the observer variables are controlled by limiting the variables in the object and the light source **(Saleski, 1972).** There are two methods used to measure the color stability of the material: subjective and objective methods.

1.4.1. Subjective methods:

The subjective methods are pursued by visual grading of stain according to a non-parametric ranking of the area and/or the intensity of discoloration. The visual examination of staining can be assessed by independent observers. The samples are evaluated visually for staining by comparing the tested samples with the control group by placing the specimens on a white background and they are graded for the amount of staining on a scale of: no, slight, mild, moderate, and severe **(Kuehni and Marcus, 1979; Sheen and Harrison, 2000).**

1.4.2. Objective method:

While objective methods follow an instrumental approach for color measurement such as colorimeter, spectrophotometer, and computer image analysis **(Addy *et al.,* 1979; Addy and Prayitno, 1980; Tantbirojn and Douglas, 2004).**

1.4.2.1. Colorimeter:

A colorimeter is device used to measure the absorbance of a specific solution. It allows the absorbance of a solution at a particular wavelength of light to be determined. The most common application of a colorimeter is to determine the concentration of a known solute. Different chemical substances absorb different wavelengths of light. The concentration of a solute is proportional to the absorbance **(Koutayas *et al*., 2003).**

1.4.2.2 .Computer image analysis:

Sheen and Harrison (2000) showed that the analysis of digital images gave similar results as the visual scoring method.

1.4.2.3. Quantitative light-induced fluorescence (QLF):

The underlying principle of the QLF technique is that teeth will auto fluorescence under certain light conditions, and that dematerialized enamel will fluoresce less than sound enamel. When examined under the QLF, dematerialized lesions appear as dark areas. With analytical software, the loss of fluorescence characteristic of dematerialized areas can be compared with the unaffected fluorescence of the sound enamel and a quantifiable value (ΔQ) reported **figure 1-14**. **(Pretty *et al*., 2001)**

Figure 1-14: The QLF hand piece (Pretty et al., 2001).

1.4.2.4. Spectrophotometer:

Spectrophotometers are useful in the measurement of surface color**.** Historically, but there are also spectrophotometers that use arrays of photo sensors and, especially in the infrared sector. There are spectrophotometers that use a Fourier transform technique to acquire the spectral information in a technique called Fourier Transform Infrared **(Berns *et al.*, 2000).**

The spectrophotometer measures quantitatively the fraction of light that passes through a given solution. In a spectrophotometer, a light from a lamp in a near - infrared / visual / ultraviolet spectrophotometer (typically a deuterium gas discharge lamp) is guided through a monochromatic, which picks light of one particular wavelength out of the continuous spectrum. This light passes through the sample that is being measured. After the sample, the intensity of the remaining light is measured with a photodiode or other light sensor, and the transmittance for this wavelength is then calculated, this method has been extensively used to measure the amount of staining **(Seghi *et al.*, 1986; Sharif *et al.*, 2000; Watts and Addy, 2001).**

Of all devices, a spectrophotometer is the most accurate for absolute color measurement. These instruments have a longer working life than colorimeters and are unaffected by object metamerism. (**Berns *et al.*, 2000; Paravina and Powers, 2004).**

Currently, there are several electronic shade-matching instruments available for clinical use. **(Okubo *et al.*, 1998; Yap et al., 1999; Paul *et al.*, 2002).**

1.4.3. The CIE Color Systems:

The CIE, or Commission Internationale de l'Eclairage (translated as the International Commission on Illumination), is the body responsible for international recommendations for photometry and colorimetry. In 1931 the CIE standardized color order systems by specifying the light source (or illuminants), the observer and the methodology used to derive values for describing color. **(Hunter and Richard. 1948)**

The CIE Color Systems utilize three coordinates to locate a color in a color space. These color spaces include: **(Stephen and Caterina, 2004)**

- CIE XYZ
- CIE L*a*b*
- CIE L*C*h*

1.4.3.1. CIE XYZ color space:

It’s also known as CIE 1931 color space, Created by the International Commission on Illumination) CIE) 1931 **(Nassau, 1998).** The CIE XYZ color space was derived from a series of experiments done by **W. David Wright (1928)** and **John Guild in (1931).**

Their experimental results were combined into the specification of CIE RGB (red, green and blue) color space, from which the CIE XYZ color space was derived **(Trichromatic Theory, Young, 1800’s)**. The trichromatic color theory stated that all colors could be created with three wavelengths, with red, green, and blue making up the dominant color of the wavelengths. XYZ are known as tristimulus values X (red), Y (green) and Z (blue) from 380-780 wavelengths **(Sangwine and Horne, 1998).**

The color matching functions are the numerical description of the chromatic response of the observer. The CIE has defined a set of three color-matching function , called $x^{-}(\lambda)$, $y^{-}(\lambda), z^{-}(\lambda)$ which can be thought of the Spectral sensitivity curves of three linear light detectors that yield the CIE XYZ tristimulus values X, Y and Z **(Figure 1.15)**, The tabulated numerical values of these functions are known collectively as the CIE standard Colorimetric observer **(Nassau, 1998)**.

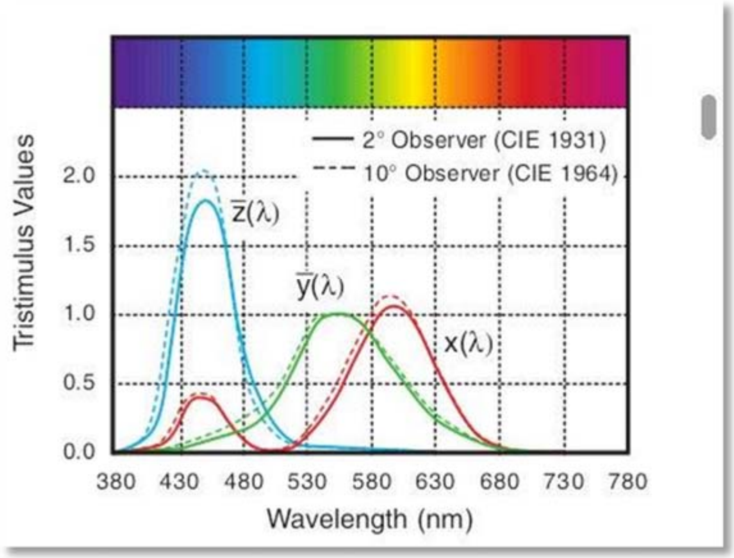

Figure 1-15: the CIE standard observer color matching function (average human response to wavelengths of light) (Nassau, 1998)

1.4.3.2. (CIE L*a*b*) L*a*b* color space:

According to **Daniela *et al.* (2009)** The color alterations were calculated using the CIE L*a*b* System, established by the "Commission Internationale de l'Eclairage – CIE**;** This approach follows the idea that somewhere between the eye and the brain, information from cone receptors in the eye gets coded into light-dark, red-green, and yellow blue signals. The concept follows the "opponent" basis that a color cannot be red and green at the same time, or yellow and blue at the same time. However, a color can be considered as a combination of red and yellow, red and blue, green and yellow, or green and blue. In the CIE L*a*b* uniform color space, the coordinates are:

- **L*** - the lightness coordinate.
- **a*** - the red/green coordinate, with +a* indicating red, and -a* indicating green.
- **b*** - the yellow/blue coordinate, with +b* indicating yellow, and -b* indicating blue **(figure 1-16):**

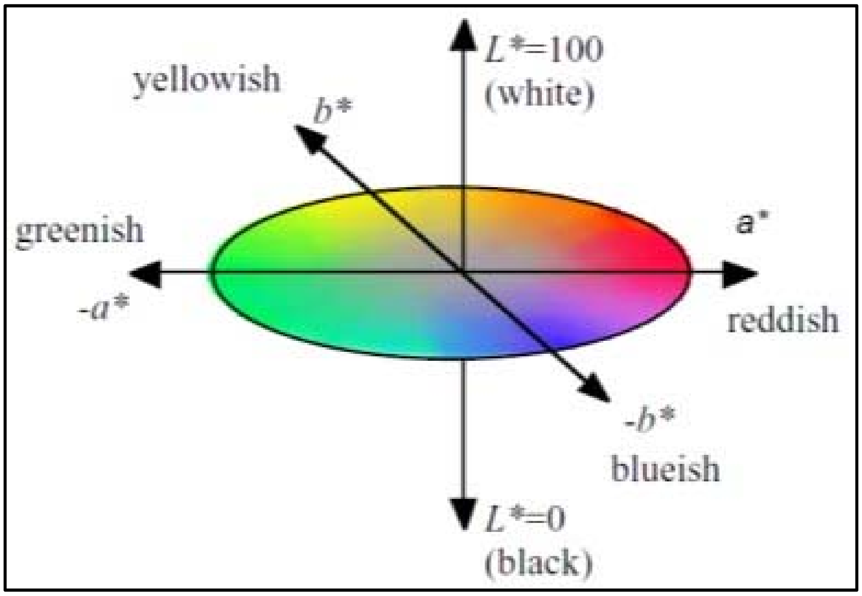

Figure 1-16: CIELAB color space. (Monique, 2013)

1.4.3.3. CIE L*C*h:

A color can also be described and located in CIELAB color space using an alternate method, that of specifying its L*, C,* and h* coordinates. In this method, the L* coordinate is the same as in L*a*b*, while the C* and h* coordinates are computed from the a* and b* coordinates. The same color is still in the same location in the color space, but there are two different ways to describe its position (L*a*b* or L*C*h*); The L*C*h* color space is also three dimensional, but the color is located using cylindrical coordinates, as follows: **(Monique, 2013)**

- L* - the lightness coordinate, same as in L*a*b.*
- C* - the Chroma coordinate, the distance from the lightness axis.
- H* - the hue angle, expressed in degrees, with 0° being a location on the +a* axis, then continuing to 90° for the +b* axis, 180° for -a*, 270° for -b*, and back to 360° = 0°. **(figure 1-17)**

Many CIE system users prefer the L*C*h* method of specifying a color, since the concept of hue, and Chroma agrees well with visual experience **(CIE, 1985)**

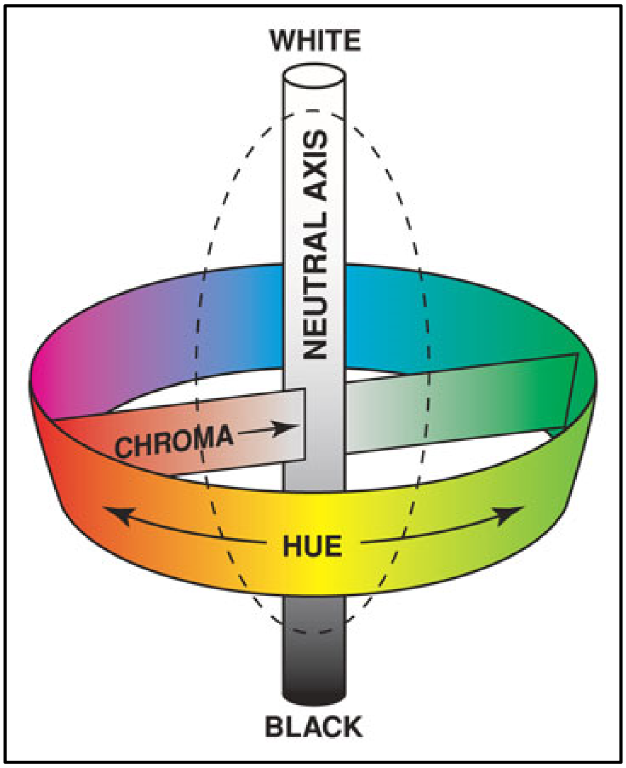

Figure 1-17: alternate CIELAB color space (CIE, 1985)

1.4.4. The color alterations measurement:

To obtain these values, we must understand how they are calculated; as stated earlier, our eyes need three things to see color: a light source, an object and an observer/processor. The same must be true for instruments to see color. Color measurement instruments receive color the same way our eyes do by gathering and filtering the wavelengths of light reflected from an object. The instrument perceives the reflected light wavelengths as numeric values. These values are recorded as points across the visible spectrum and are called spectral data. Spectral data is represented as a spectral curve. This curve is the color's fingerprint **(Figure 1.18). (Schulze *et al.*, 2003; Arikawa, 2007; Chris *et al.*, 2013)**

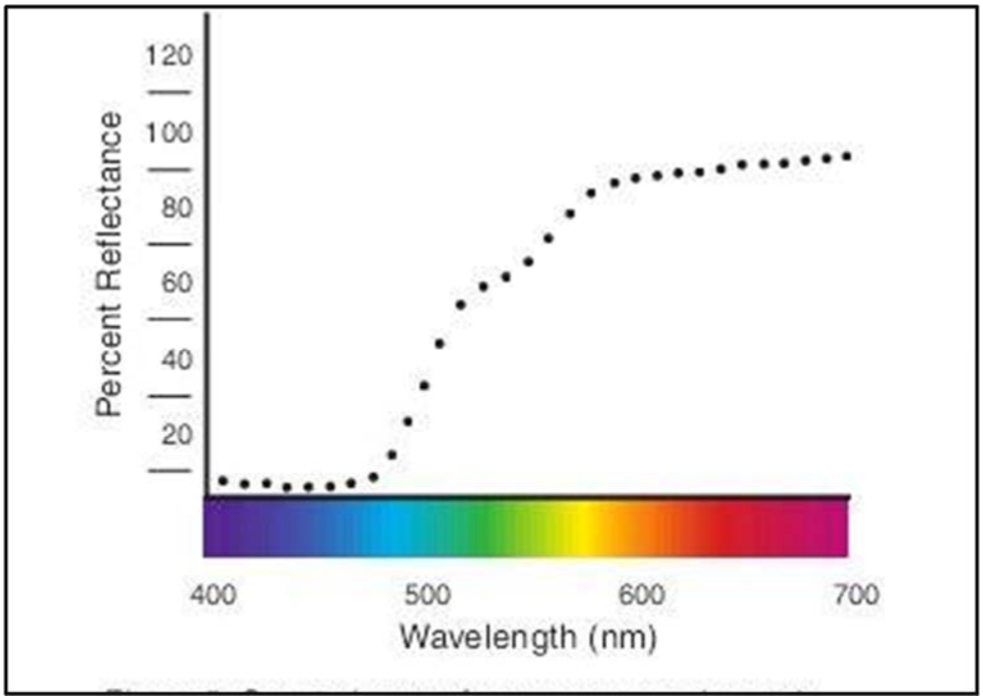

Figure 1.18: Spectral curve from a measured sample (Chris *et al*., 2012)

Once we obtain a color's reflectance curve, we can apply mathematics to map the color onto a color space.

To do this, we take the reflectance curve and multiply the data by a CIE standard illuminant. The illuminant is a graphical representation of the light source under which the samples are viewed.

Each light source has a power distribution that affects how we see color. Examples of different illuminants are A — incandescent, D65 — daylight **(Figure 1-19),** and F2 — fluorescent. We multiply the result of this calculation by the CIE standard observer. The CIE commissioned work in 1931 and 1964 to derive the concept of a standard observer, which is based on the average human response to wavelengths of light **(Figure 1-15) (X-Rite brochure 2000; X-Rite brochure, 2007; Chris *et al*., 2013)**

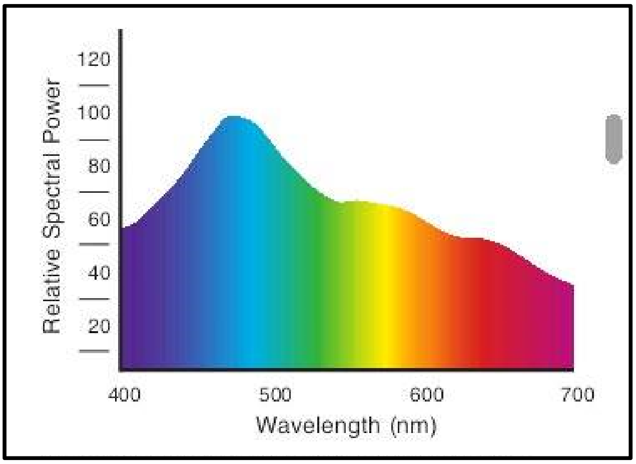

Figure 1.19: Daylight (Standard Illuminant D65/10°)

(X-Rite brochure, 2007)

In short, the standard observer represents how an average person sees color across the visible spectrum. Once these values are calculated, we convert the data into the tristimulus values of XYZ (Figure 1-20). These values can now identify a color numerically **(Hunter and Harold, 1980)**

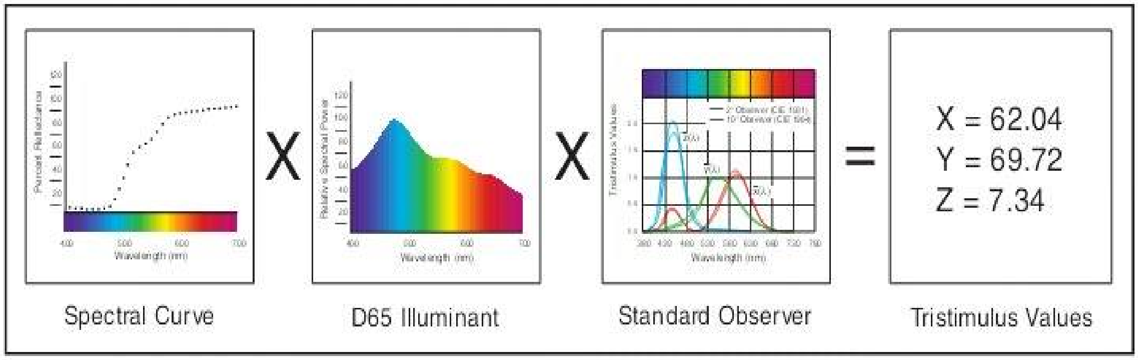

Figure 1-20: Tristimulus values (X-Rite brochure, 2007)

A Tristimulus values can be converted to L*a*b* values when:

$$L* = 116(Y/Yo)^{1l3} - 16$$

$$a* = 500\,[\,(X/Xo)^{1l3} - (Y/Yo)^{1l3}\,]$$

$$b* = 200\,[\,(Y/Yo)^{1l3} - (Z/Zo)^{1l3}\,]$$

Total color differences are expressed by the formula:

$$\boldsymbol{\Delta E * = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1l2}}$$

(Schanda, 2000; Schulze *et al*., 2003; Arikawa, 2007; Celik *et al*, 2008; Patel and Anand, 2012).

When the ΔE is the (amount of color change to a clinical environment, the data were converted to National Bureau of Standards (NBS) units **(Nimeroff, 1968)** as follows:

$$\textbf{NBS units} = \Delta \textbf{E} \times \textbf{0.92}$$

The definitions of color changes quantified by NBS units were used. These values were suggested by **Koksal and Dikbas in 2008.**

Chapter Two

Materials and Methods

2.1. Materials:

The following materials, equipment's and supplies were used in the present study:

2.1.1. Aesthetic archwires:

Upper stainless steel coated aesthetic archwires with different coating material and from different companies were used as the following:

2.1.1.1. Polytetrafluoroethylene (PTFE) coating material archwires

Which include as shown in **figure 2-1(a, b):**

a. **Hubit company / Korea** : stainless coated 0.019 * 0.025 of an inch archwires (REF:CAW 120706-15) (LOT :2012.07.06)

b. **Dany BMT Company / Korea** : stainless coated 0.019 *0.025 of an inch archwires (REF : DW-SOL-1925) (LOT: 362426)

2.1.1.2. Epoxy coating material archwires:

Which include as shown in **figure 2-2(a, b):**

a. **Ortho technology company / U.S.A.** : stainless coated 0.019 * 0.027 of an inch archwires (REF:8000-813) (LOT :432200613)

b. **G &H Wire company / U.S.A.** : stainless coated upper 0.019 *0.025 of an inch archwires (REF:1925T) (LOT: 143177)

(A) Hubit coated archwires **(B) Dany coated archwires**

Figure 2-1: PTFE coated archwires

(A) Orthotechnology coated archwires **(B) G&H coated archwires**

Figure 2-2: Epoxy coated archwires

2.1.2. staining solution preparation materials :

Two types of staining solution were used which they are: **(figure 2-3)**

a. Pepsi cola / Baghdad Company. Expire date 17-4-2015/ Iraq

b. Ahmad tea company; tea bags / London; England. Expire date 1-2-2017/ UAE

c. Distilled water for preparation of the tea. ph. 6.8/ iraq

Figure 2-3: materials used in the preparation of the staining solution

2.1.3. Equipments , instruments and others :

Which includes: **(Figure 2-4: a and b)**

1. Cutter.
2. Stainless steel tweezers.
3. Glass containers.
4. Marker pencil.
5. Adhesive strips.
6. Light cure composit resin. (3M ESPE ; Filtek XT / USA)
7. Ethyl cyanoacrylate (Ameer) /quick star company

8. Sterilized gloves.
9. Light cure unit: Monitex; LD-107 /Taiwan.
10. Computerized UV-VIS Spectrophotometer. (uv-1800 SHIMADZU / Japan)
11. Incubator. (Fisher Scientific / USA)

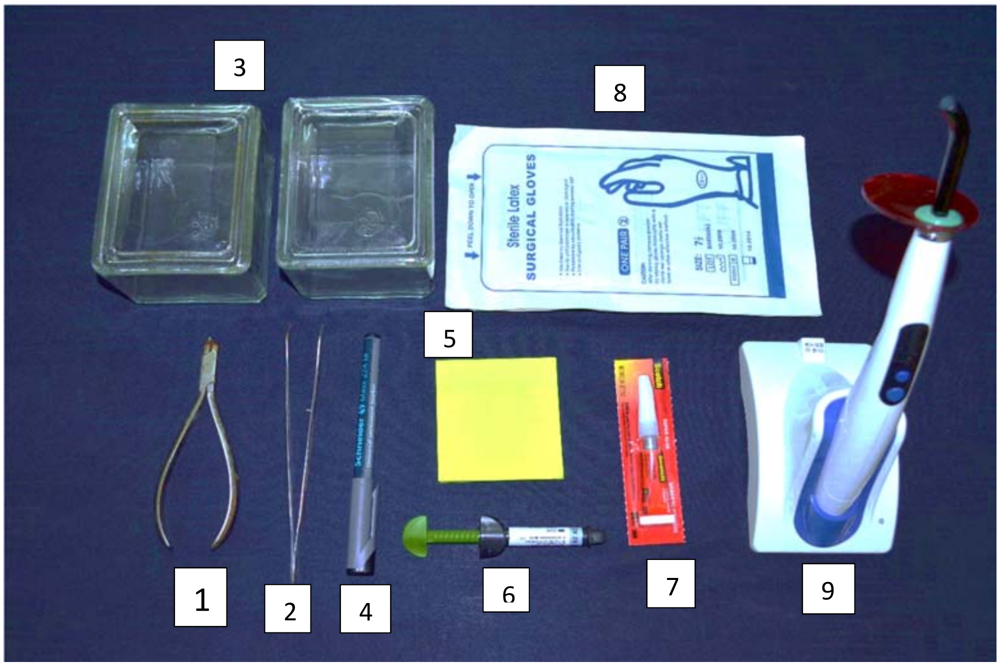

Figure 2-4a: The instruments used in the present study

Figure 2-4b: The computerized spectrophotometer used in the present study

2.2. Methods:

2.2.1. Samples preparation:

Twelve samples from each company were prepared; each sample was made by cutting the preformed archwires into two halves, then placing ten halves of the coated archwires segments together and uniting there free ends first by the light cure composit resin **(Figure 2-5)** because it has quick set so it makes it easier to use the ethyl cyanoacrylate (Ameer) for more fixation **(figure 2-6)**; so that the sample resemble a strip as shown in **Figure 2-7 (Mohammed, 2013);** the ethyl cyanoacrylate can withstand the humidity so the samples stay as strips in the staining solutions. The aesthetic coating surface of each wire segments was facing in the same direction; so that the color could be properly measured.

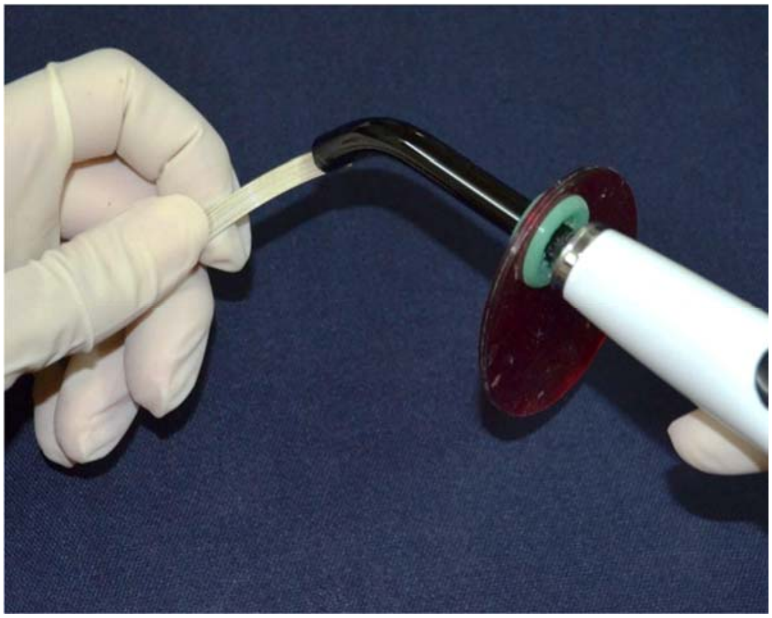

Figure 2-5: Uniting of ten halves of the coated archwires segments together by Light cure composit resin

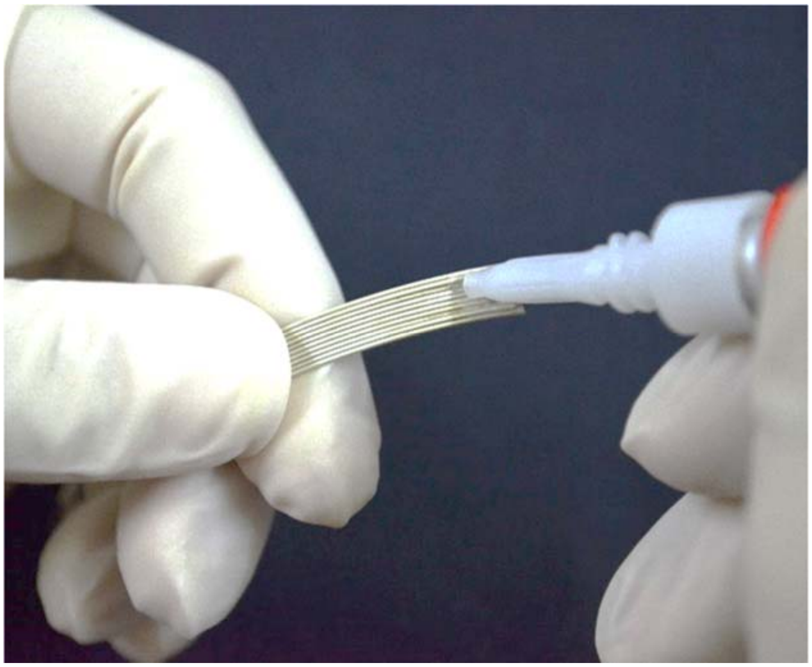

Figure 2-6: Uniting of ten halves of the coated archwires segments together by Ethyl cyanoacrylate

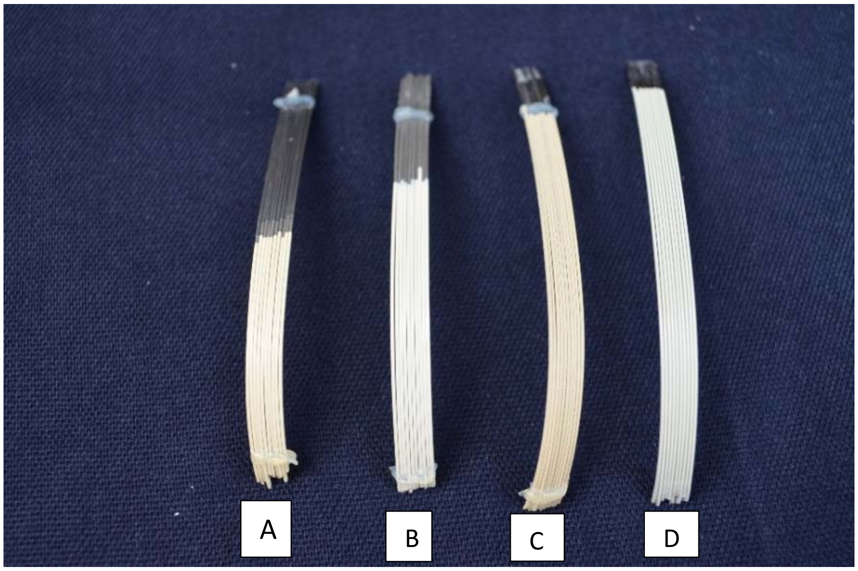

Figure 2-7: Samples from each company which resemble a strip

A: Dany company B: Hubit company C: G&H company

D: Orthotechnology company

2.2.2. The samples grouping:

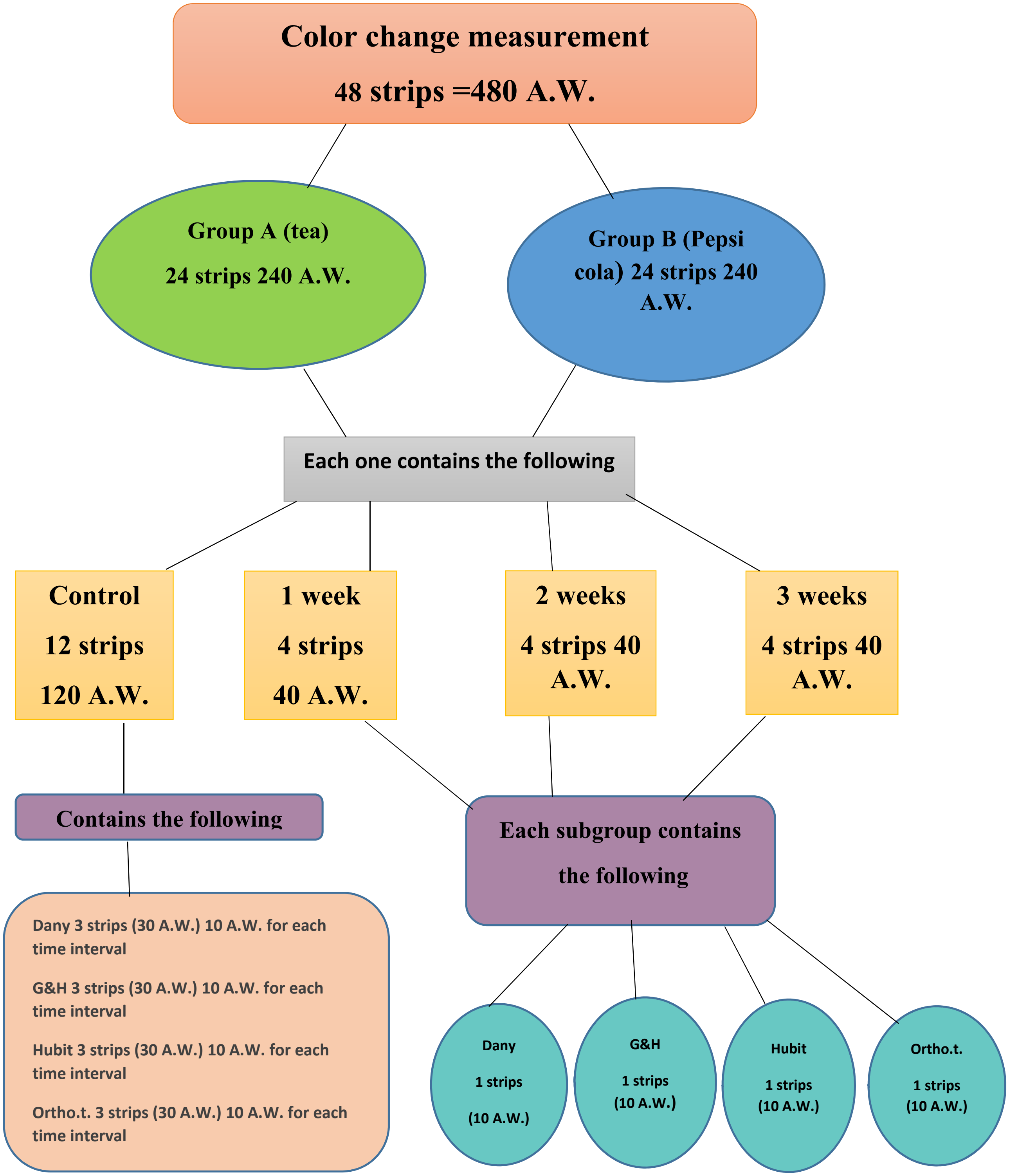

Figure 2-8: Schematic view of the sample grouping

2.2.3. Preparation of staining solutions:

Fresh preparation of the staining drinks was made as the following:

2.2.3.1. Tea:

A standard solution of tea was prepared so that five tea bags of a commercial brand (Ahmad tea company; tea bags / London; England.) was boiled in 500 milliliters of distilled water for 4 minutes after beginning of boiling and allowed to cool at room temperature (about 30$\overset{o}{c}$) . The solution was replaced four times daily each 6 hours to prevent the precipitation and change in concentration **(Imad.2013)**

2.2.3.2. Pepsi cola:

Cans of Pepsi cola were used at the room temperature (about 30$\overset{o}{c}$); they were replaced twice daily to prevent the precipitation **(Imad, 2013)**.

2.2.4. Color Measurements:

The color was assessed using a spectrophotometer with xenon lamp as light source, according to Commission Internationale de l’Eclairage (translated as the International Commission on Illumination) **CIE 1976 L*a*b’*** color space system relative to the standard illuminant D65 and observer Emotions

2.2.4.1. Baseline measurement of color change:

After numbering the specimens of each subgroup from 1 to 4 for tea and 1 to 4 for Pepsi cola by the marker pencil which couldn’t be removed by the solutions, they were incubated in distilled water in glass container at 37°C for 24 hours using incubator, baseline measurements was done as follow:

1. The top surfaces of the specimens always were centered in front of xenon lamp (light source of spectrophotometer) in center of a spectrophotometers tube, so repetitive measurements for each specimen could be taken from the same specimen's region. **Figure 2-9 (Koksal and Diltbas, 2008).**

Figure (2-9): the specimen was centered in front of xenon lamp (light source of spectrophotometer) in center of a spectrophotometers tube

2. Measure the light reflection of each specimen by spectrophotometer at visible wavelengths started from 400-700 **nm** at 10 **nm** intervals so for each specimen, thirty one value of light reflection were obtained. **(Craig and Powers, 2002).**
3. Calculated tri-stimulus values X, Y and Z for each specimen from the follow equations **(Hunter and Harold 1980):**

$$X=100\,\frac{\int E_\lambda R_\lambda \bar{x}_\lambda\, d_\lambda}{\int E_\lambda\, \bar{y}_\lambda d_\lambda} \qquad \ldots\ldots\ldots\ldots 1$$

$$Y=100\,\frac{\int E_\lambda R_\lambda \bar{y}_\lambda d_\lambda}{\int E_\lambda\, \bar{y}_\lambda d_\lambda} \qquad \ldots\ldots\ldots\ldots 2$$

$$Z=100\,\frac{\int E_\lambda R_\lambda \bar{Z}_\lambda d_\lambda}{\int E_\lambda\, \bar{y}_\lambda d_\lambda} \qquad \ldots\ldots\ldots\ldots 3$$

Where:

E*λ*= Standard illuminants D65 at a given wavelength.

R *λ*= Reflection of object at a given wavelength.

λ =Wave length of measurement.

∫ = Mathematical integration.

x-, y-, z- = Components of the standard observer function.

d *λ* = Derivative sign. (Will be listed in the appendix)

The values of **E λ, x-, y-and z-** took from table containing standards for them corresponding to wave-lengths, these values start from **380-730 nm** wavelengths. After calculating the **R** of each specimen from **400-700 nm** at **10 nm** intervals, select the values of **E*λ*, x-, y-and z-** from **400-700 nm** at **10 nm** intervals.

Example if measured the reflection of specimen at **400 nm** wavelength, select the values of **E *λ*, x-, y-and z-** at **400 nm** also and applied in equation l, 2 and 3 and so on for all selected wavelengths (31 ***λ***).

4. Take the mathematical integration for thirty one value by using software program **(MATLAB 8 software, R2012b, 2012/ USA)** then one value for X, Y and Z obtained.
5. The same steps for measuring X, Y and Z values for each specimen were follow for measuring X, Y and Z values for standard white card with 100% reflection values at **400-700 nm** wavelengths and recorded as Xo, Yo and Zo.

Measured L*, a* and b* from X, Y and Z values that previously measured us follow: **(Schanda, 2000; Schulze *et al.*, 2003; Arikawa, 2007; Celik *et al*, 2008; Patel and Anand, 2012).**

$$\boldsymbol{L \ast = 116(Y/Yo)^{1l3} - 16}$$

$$\boldsymbol{a \ast = 500\ [\ (X/Xo)^{1l3} - (Y/Yo)^{1l3}\ ]}$$

$$\boldsymbol{b \ast = 200\ [\ (Y/Yo)^{1l3} - (Z/Zo)^{1l3}\ ]}$$

Where is:

X, Y, Z	tristimulus values previously measured
X0, Y0, Z0	X, Y, Z values of a perfect white sample (standard)
L*	CIE Lab L - value (lightness in Lab color space)
a*	CIE Lab a - value (red — green value)
b*	CIE Lab b - value (yellow - blue value)

6. The L*, a* and b*values of each specimen consider as baseline measurement for color stability of the coating material of the aesthetic archwires.

2.2.4.2. Measurement of the color change after immersion in the staining solutions:

1. The samples were placed in a glass container at its side so the labial doesn't touch the container, with the prepared staining solutions (tea and Pepsi cola), then

incubated in the incubator at **37^{o}c** which is the temperature of the human body as shown in **Figure 2-10: a and b:**

Color measurements were repeated after 7 days **(T1)**, 14 days **(T2),** and 21 days **(T3)** of immersion in the solution.

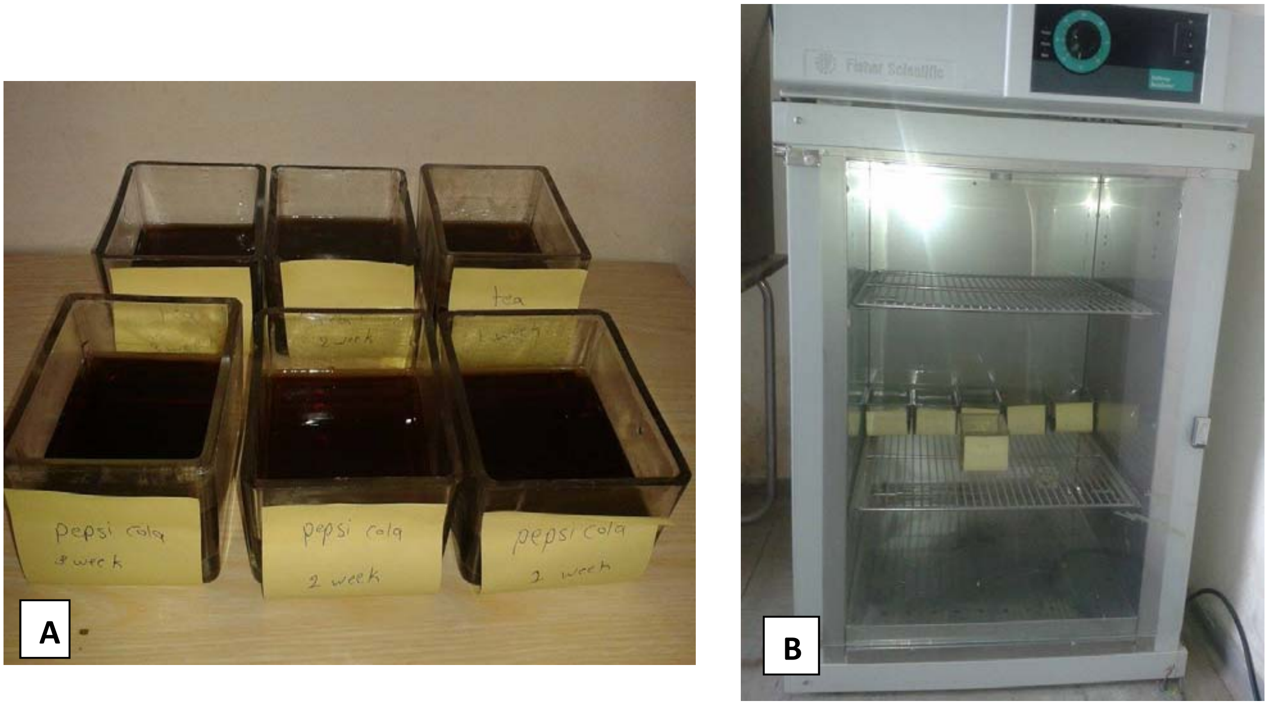

Figure 2-10: The samples were placed in a glass container with the prepared staining solutions (tea and Pepsi cola) on the incubator

(a) The samples immersed in the solutions (b) The samples were at the incubator

2. Before each measurement, samples were removed from the solution and rinsed with distilled water for 5 minutes. Excess water on the surfaces was removed with tissue papers, and the samples were allowed to dry. **(Imad, 2013; Silva *et al*., 2013)**

3. Measured the **L*, a***and **b*** values of each specimen after immersion in treatment solutions by the same method followed in baseline measurement **(Diab *et al*, 2000)**. The specimen was distinguished by a number placed at the end of the sample by a marker pencil.

4. Calculated Color difference between baseline measurement and measurement after immersion in solution as follows **(Schanda, 2007):**

$$\Delta L^* = L_2 - L_1$$

$$\Delta a^* = a_2 - a_1$$

$$\Delta b^* = b_2 - b_1$$

Where is:

$\Delta L^*, \Delta a^*, \Delta b^*$	color differences in the CIE L*a*b* color space
L_1, a_1, b_1	L*a*b* values of sample (baseline measurement)
L_2, a_2, b_2	L*a*b* values of the same sample (after immersion)

If ΔL^* + means sample after immersion is lighter than before immersion

If ΔL^* - means sample after immersion is darker than before immersion

If Δa^* + means sample after immersion is more red than before immersion

If Δa^* - means sample after immersion is greener than before immersion

If Δb^* + means sample after immersion is yellower than before immersion

If Δb^* - means sample after immersion is bluer than before immersion.

5. Calculate total color dereference **Δ E*** for each specimen (distance between the 2 point in color space) by following equation **(Celik et al, 2008):**

$$\Delta E* = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1l2}$$

Then compare the **Δ E*** of each subgroup with others, to distinguish which type of coating material was more unstable in color and which staining solution cause more color change in aesthetic archwires , the aesthetic archwires after immersion in the staining solution is shown in **figure 2-11 & 2-12**:

Then we relate the amount of color change **(Δ E*)** to a clinical environment, the data were converted to National Bureau of Standards **(NBS)** units as the following: **(Nimeroff, 1968)**

$$\text{NBS units} = \Delta E^* \times 0.92$$

Table 2-1 Critical Marks of Color Change According to the National Bureau Standards (Nimeroff, 1968)

NBS Unit	Definitions of Color Differences	
0.0–0.5	**Trace**	**Extremely slight change**
0.5–1.5	**Slight**	**Slight change**
1.5–3.0	**Noticeable**	**Perceivable change**
3.0–6.0	**Appreciable**	**Marked change**
6.0–12.0	**Much**	**Extremely marked change**
12.0+	**Very much**	**Change to other color**

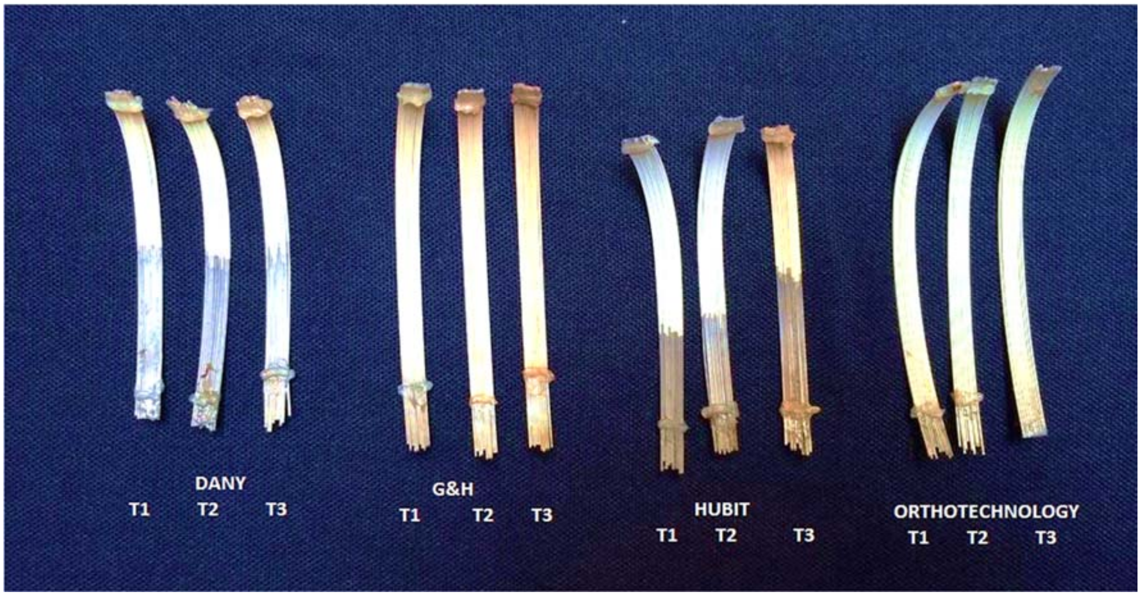

Figure 2-11: The samples after immersion in Pepsi cola at all-time intervals

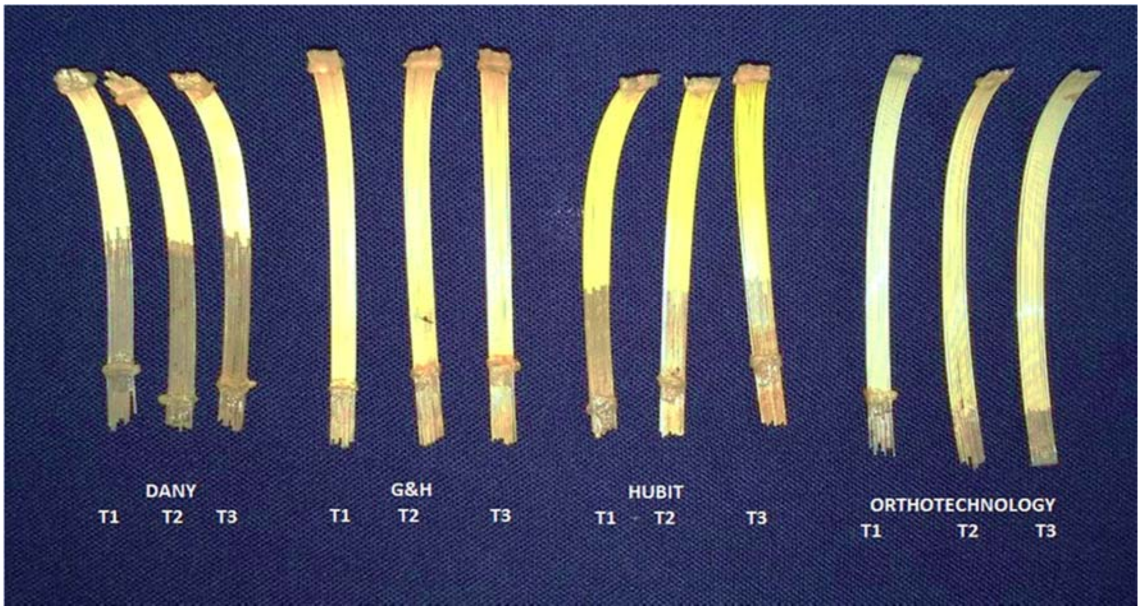

Figure 2-12: The samples after immersion in tea at all-time intervals

2.3. Pilot study:

Several trails had been done on the spectrophotometer to check that the machine is worked properly and the readings are correct, the pilot study was also done to insure that the samples width is enough to be scanned by the spectrophotometer and to insure that the immersion time is good enough to made a color change in the aesthetic archwires in a way that it could be detected by the spectrophotometer.

2.4. Statistical Analysis:

In this study, the Statistical methods which were used in order to analyze and assess the results:

A- Descriptive statistics:

1. Arithmetic mean

2. Standard Deviation **SD**, maximum **(Max.)** and minimum **(Min.)**

3. Bar Charts

B- Inferential statistics:

1. One Way ANOVA.

2. LSD test (least significance difference test)

Chapter three

Results

The color stability of the aesthetic archwires from different companies that were treated by two different staining drinks (Tea, Pepsi Cola), was measured by the amount light reflection of each specimen by computerized spectrophotometer at visible wavelengths started from **400-700 nm** as shown in **figure 3-1:**

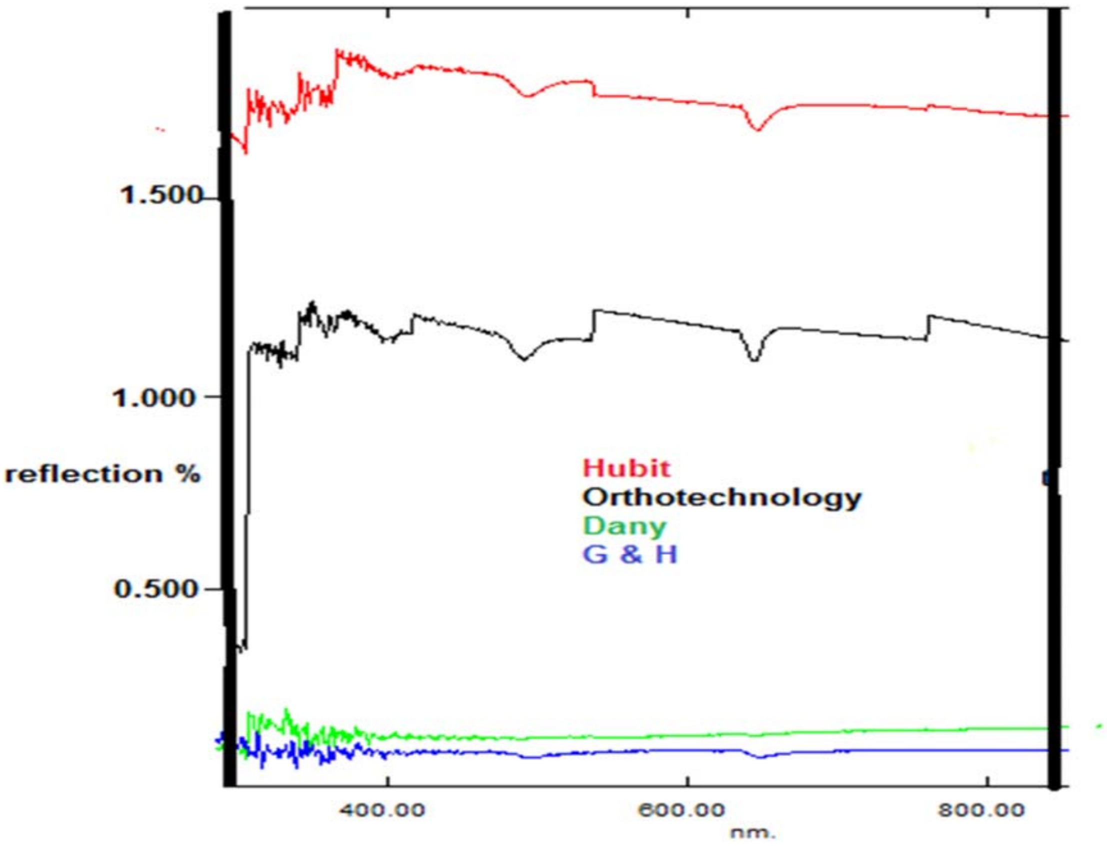

Figure 3-1: the amount of light reflection measured by computerized spectrophotometer controlled samples of all Companies

Then the result converted into L*, a* and b* according to CIE L*a*b* Created by the International Commission on Illumination and the following result were obtained:

3.1. Descriptive statistics of all companies:

Means, standard deviation **(SD)**, minimum **(Min)** and maximum **(Max)** values of **ΔL*, Δa*, Δb*and ΔE*** of aesthetic archwires from four different companies **(Dany , G&H, Hubit and Orthotechnology)** at all-time intervals of immersion in two different staining drinks **(Tea and Pepsi cola)** listed in tables **3-1 ,-3-2** and shown in figures **3-2:a&b and 3-3:**

Table 3-1: Descriptive statistics of ΔL*, Δa*, Δb* values of the 4 companies after 3 weeks of immersion in Tea and Pepsi cola

Subgroup		Descriptive statistics											
		ΔL*				Δa*				Δb*			
		mean	SD±	Min.	Max.	Mean	SD±	Min.	Max.	Mean	SD±	Min.	Max
Tea	D	-13.561	2.563	-18.31	-9.305	2.164	0.445	-1.577	5.382	1.190	1.118	-6.53	5.287
	G	-16.53	2.924	-22.158	-12.924	1.555	0.533	-0.304	4.162	3.062	0.908	-0.832	6.37
	H	-17.831	1.347	-20.707	-16.211	-7.556	1.451	-8.754	-3.163	33.14	5.436	17.09	36.88
	Or	-9.817	3.263	-16.951	-4.976	-0.029	0.008	-1.801	1.494	1.056	0. 62	-2.064	7.765
Pepsi cola	D	-6.578	1.273	-8.471	-4.523	0.014	0.005	-0.857	1.364	0.721	0.087	-2.746	2.654
	G	-7.832	2.873	-11.766	-2.045	0.774	0.025	0.164	1.698	-1.001	0.944	-3.051	-0.13
	H	-11.93	0.843	-13.007	-10.598	-0.233	0.031	-0.915	0.509	-1.544	1.050	-4.021	0.51

	Or	**0.855**	**0.137**	**-3.958**	**3.365**	**-1.251**	**0.015**	**-2.790**	**-0.004**	**2.163**	**1.153**	**-2.798**	**5.045**

<u>Subgroups:</u>

D: Dany Company

G: G&H Company

H: Hubit Company

Or: Orthotechnology Company

<u>Where are*:</u>

ΔL*, Δa*, Δb*	color difference in **CIE L*a*b*** color space

ΔL*- the lightness coordinate.

Δa*- the red/green coordinate, with +a* indicating red, and -a* indicating green.

Δb*- the yellow/blue coordinate, with +b* indicating yellow, and -b* indicating blue.

- If **Δ L*** + means sample after immersion is lighter than before immersion.
- If **Δ L*** - means sample after immersion is darker than before immersion.
- If **Δ a*** + means sample after immersion is more red than before immersion.
- If **Δ a*** - means sample after immersion is greener than before immersion.
- If **Δ b*** + means sample after immersion is yellower than before immersion.
- If **Δ b*** - means sample after immersion is bluer than before immersion.

Table (3-2) Descriptive statistics of ΔE* values of the 4 companies and for both staining solution (Tea and Pepsi cola) after 3 weeks of immersion

Subgroup		Descriptive statistics			
		ΔE*			
		Mean	SD±	Min.	Max.
Tea	**D**	14.056	2.986	9.383	19.751
	G	19.461	3.261	15.740	25.689
	H	39.687	4.244	27.297	42.899
	Or	17.225	4.218	3.618	19.214
Pepsi cola	**D**	6.847	1.301	4.966	8.891
	G	9.898	1.947	6.247	13.303
	H	11.983	0.882	10.6	13.176
	Or	3.256	0.737	2.119	4.608

Subgroups:

D: Dany Company

G: G&H Company

H: Hubit Company

Or: Orthotechnology Company

<u>Where are*:</u>

ΔE* The amount of total color change

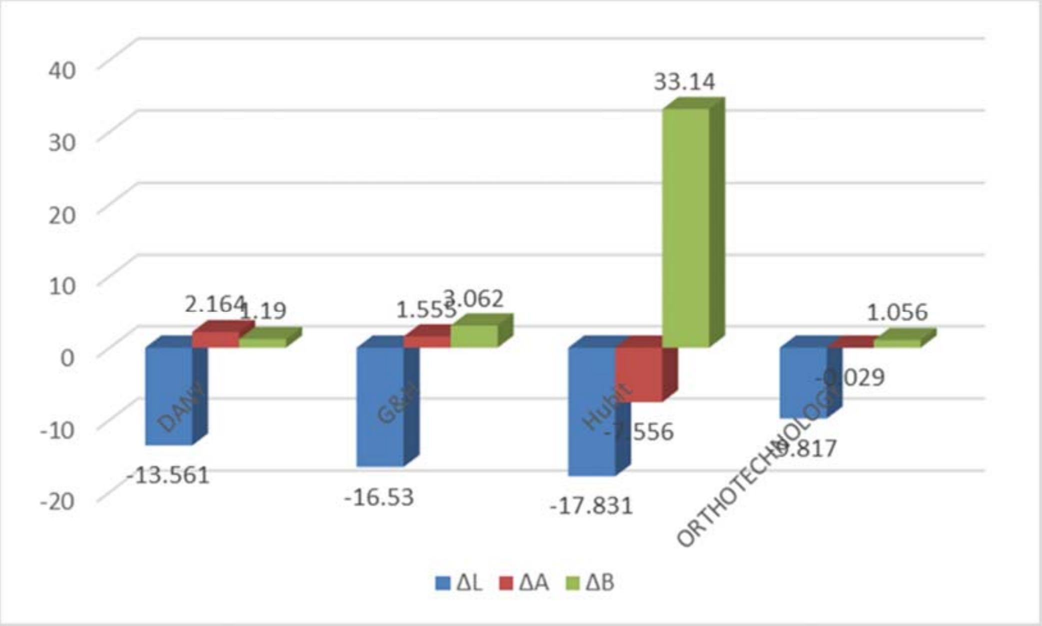

Figure 3-2.a: Bar chart shows the mean of ΔL*, Δa*, Δb* of all companies after immersion in TEA

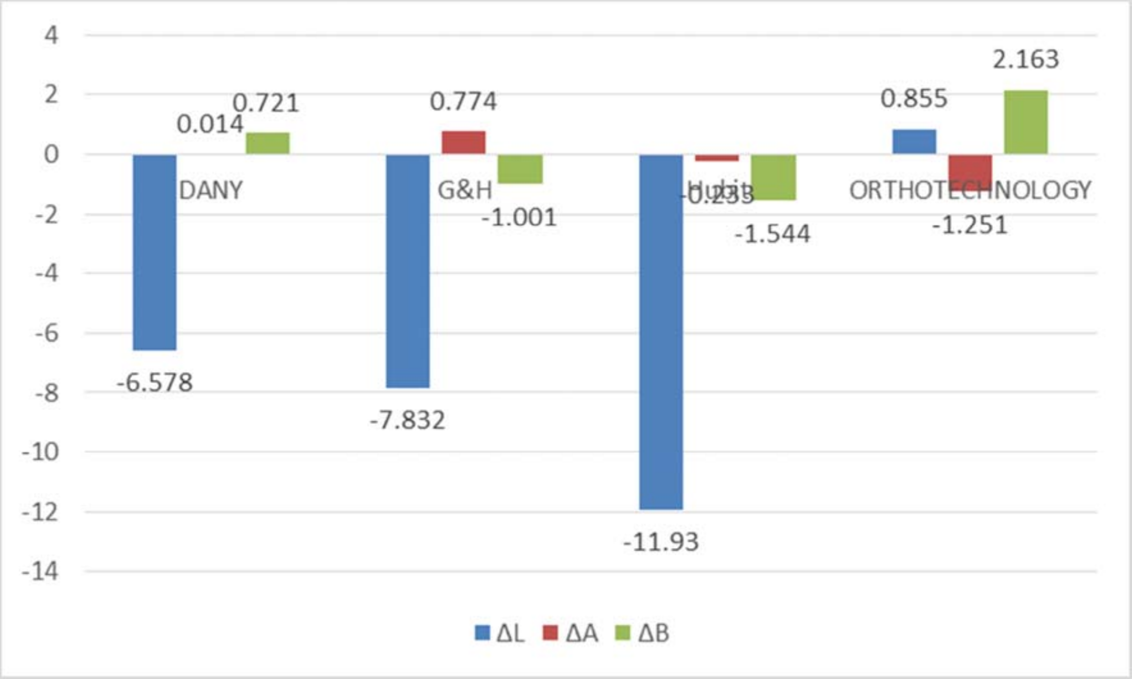

Figure 3-2.b: Bar chart shows the mean of ΔL*, Δa*, Δb* of all companies after immersion in Pepsi cola

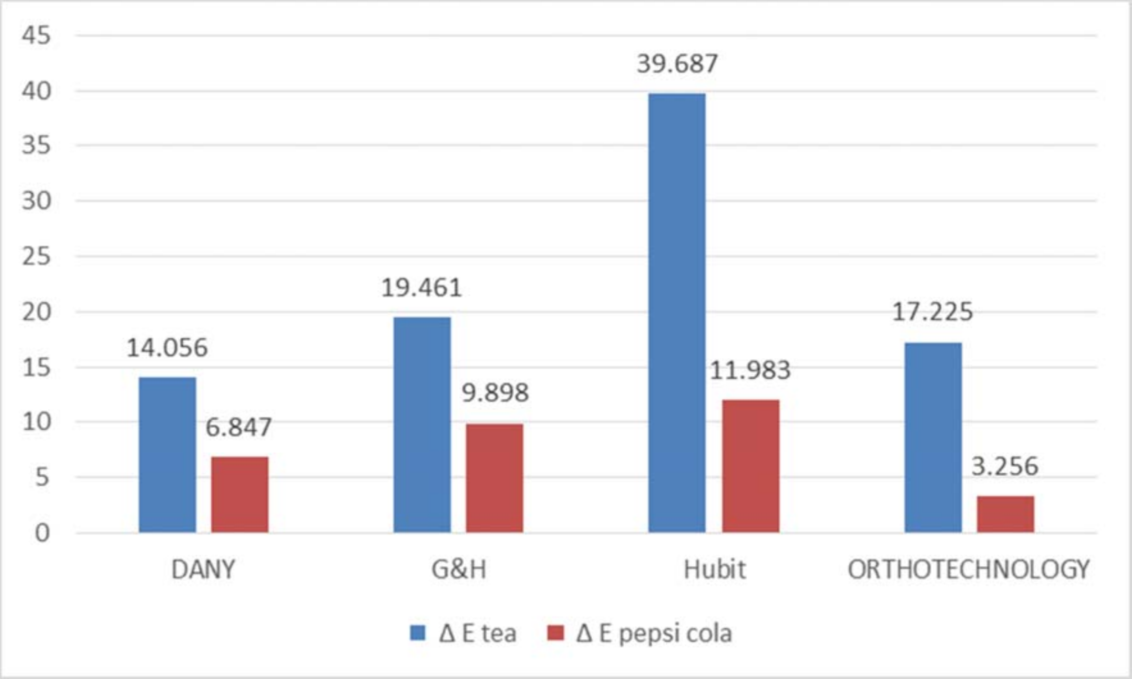

Figure 3-3: Bar chart shows the mean of ΔE*of all companies after immersion in Pepsi cola & tea

3.2. Descriptive and inferential statistics of subgroup 1 (DANY company)

3.2.1. Descriptive statistic:

Means, standard deviation **(SD)**, minimum **(Min)** and maximum **(Max)** values of **ΔL*, Δa*, Δb*** and **ΔE*** of aesthetic archwires from Dany company for all time intervals of immersion in two different staining drinks (Tea and Pepsi cola) listed in tables **3-3 & 3-4** and shown in **figures 3-4:a&b, and 3-5**:

Table 3-3: Descriptive statistics of ΔL*, Δa*, Δb* values from DANY Company after immersion in PEPSI cola and TEA for all time intervals

		Week1			Week2			Week3		
		Δ L	Δ a	Δb	Δ L	Δ a	Δb	Δ L	Δ a	Δb
	Mean	-9.554	-0.205	1.1996	-13.52	0.481	3.281	-13.56	2.164	1.190
TEA	SD	2.042	0.039	0.787	2.242	0.062	0.676	2.563	0.445	0.17
	MAX	-7.688	0.674	6.165	-8.748	1.285	7.2	-9.305	5.382	5.287
	MIN	-15.74	-1.386	-0.731	-16.88	-0.988	0.58	-18.31	-1.577	-6.53
	SE	0.616	0.162	0.540	0.677	0.200	0.5064	0.774	0.6539	0.9419
PEPSI	Mean	-3.66	0.1541	0.198	-4.478	0.1541	0.198	-6.578	0.014	0.721
	SD	0.277	0.071	0.016	0.954	0.261	0.260	1.273	0.015	0.087

	MAX	-1.356	1.195	1.15	-3.044	1.195	1.15	-4.523	1.364	2.654
	MIN	-5.927	-1.191	-2.266	-5.927	-1.191	-2.266	-8.471	-0.857	-2.746
	SE	0.386	0.021	0.037	0.288	0.216	0.337	0.384	0.017	0.059

Table 3-4: Descriptive statistics of ΔE*values from DANY Company after immersion in PEPSI cola and TEA for all time intervals

		Week1	Week2	Week3
TEA	Mean	9.745627	14.00287	14.05642
	SD	2.333286	2.474529	2.986307
	MAX	16.90682	18.39076	19.75107
	MIN	7.821516	9.051693	9.383412
	SE	0.70492	0.747592	0.902208
PEPSI	Mean	3.972345	4.686238	6.847747
	SD	1.036648	0.911475	1.301364
	MAX	6.037535	6.037535	8.891434
	MIN	2.85265	3.272328	4.966937
	SE	0.313187	0.27537	0.393161

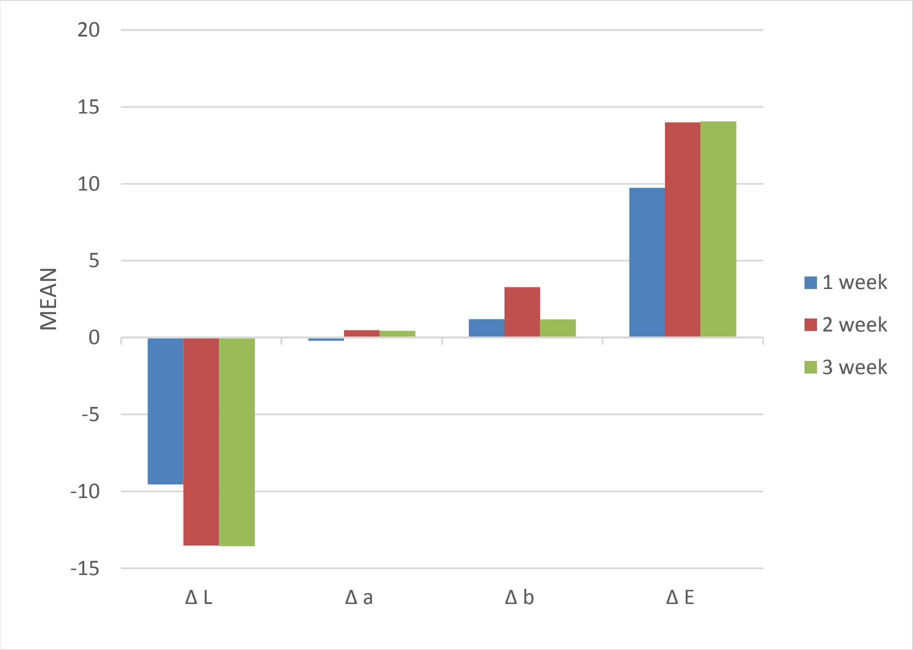

Figure 3-4a: Bar chart shows the mean of ΔL*, Δa*, Δb* & ΔE* of Dany company after immersion in TEA

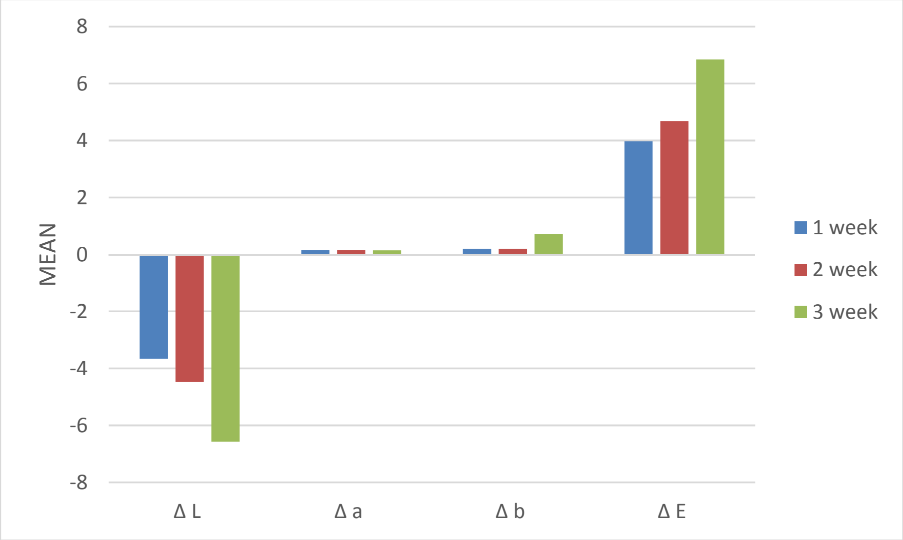

Figure 3-4b: Bar chart shows the mean of ΔL*, Δa*, Δb*& ΔE* of Dany company after immersion in Pepsi cola

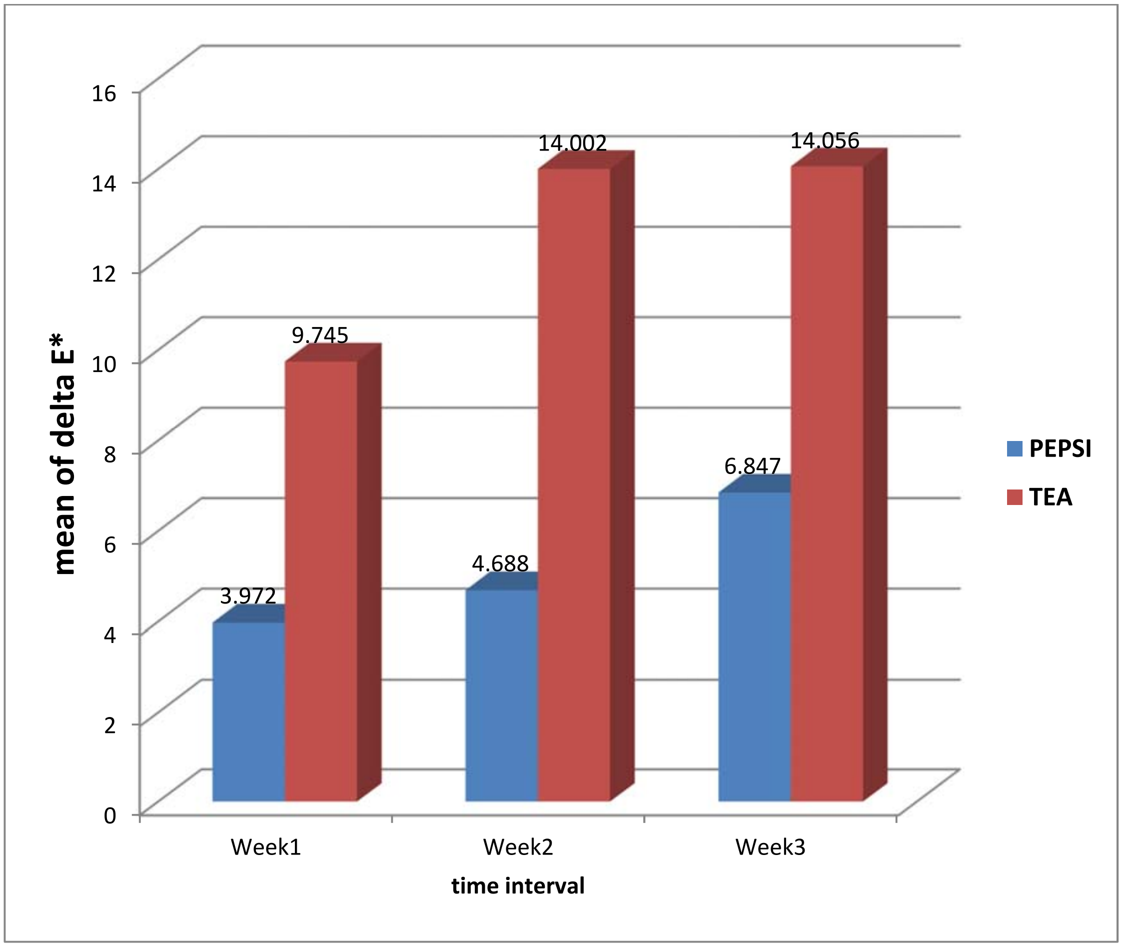

Figure 3-5: Bar chart shows the mean of ΔE* values of Dany company after immersion in TEA and Pepsi cola

3.2.2. Inferential statistics:

Analysis of variance test **(ANOVA)** and least significance difference **(LSD)** was performed to test any significant difference of **ΔL*, Δa*, Δb*** and **ΔE*** values of esthetic archwires from Dany company after immersion in the staining solution as listed in tables **3-5, 3-6, 3-7** and **3-8:**

Table 3-5: ANOVA test results for ΔL*, Δa*, Δb* values after 3 weeks of DANY company after immersion in TEA and PEPSI cola

		F-test	P-value	Sig
Tea	Δ L*	10.089	P<0.01	HS
	Δ a*	0.892	0.449	NS
	Δb*	2.767	0.049	S
Pepsi cola	Δ L*	16.311	P<0.01	HS
	Δ a*	0.145	0.866	NS
	Δb*	0.512	0.604	NS

DF=59 HS= highly significant @ P<0.01 S= significant @ P<0.05 NS= non-significant @ P>0.05

Table 3-6: LSD test results for ΔL*, Δa*, Δb* values after 3 weeks of DANY company after immersion in PEPSI cola and TEA

		Week1&Week2		Week1&Week3		Week2&Week3	
		P-value	Sig	P-value	Sig	P-value	Sig
TEA	ΔL*	0.01	S	P<0.01	HS	0.972	HS
	Δb*	0.049	S	0.993	NS	0.049	S
PEPSI	ΔL*	0.131	NS	P<0.01	HS	P<0.01	HS

HS= highly significant @ P<0.01 S= significant @ P<0.05 NS= non-significant @ P>0.05

These tables shows that there is highly significant change on Δ **L*** of the samples for both tea and Pepsi cola which means that the samples became darker after 3 weeks of immersion.

Table 3-7: ANOVA test results for ΔE* values of DANY company after 3 weeks of immersion in PEPSI cola and TEA

	F-test	P-value	Sig
TEA	**18.685**	**P<0.01**	**HS**
PEPSI	**8.960**	**0.01**	**S**

DF=59 HS= highly significant @ P<0.01 S= significant @ P<0.05 NS= non-significant @ P>0.05

This table shows that there was a highly significant change of **ΔE*** after immersion in tea which means great amount of color instability**.**

Table 3-8: LSD test results for ΔE* values of DANY company after 3 weeks of immersion in PEPSI cola and TEA

	Week1&Week2		Week1&Week3		Week2&Week3	
	P-value	Sig	P-value	Sig	P-value	Sig
TEA	**0.01**	**S**	**0.01**	**S**	**0.964**	**NS**
PEPSI	**0.155**	**NS**	**P<0.01**	**HS**	**P<0.01**	**HS**

HS= highly significant @ P<0.01 S= significant @ P<0.05 NS= non-significant @ P>0.05

3.3. Descriptive and inferential statistics of subgroup 2 (G&H company):

3.3.1. Descriptive statistic:

Means, standard deviation **(SD)**, minimum **(Min)** and maximum **(Max)** values of **ΔL*, Δa*, Δb*** and **ΔE*** of aesthetic archwires from G&H company after all time intervals in two different staining drinks (Tea and Pepsi cola) listed in tables **3-9 & 3-10** and shown in figures **3-6:a&b and 3-7**:

Table 3-9: Descriptive statistics of ΔL*, Δa*, Δb* values from G&H Company after immersion in PEPSI cola and TEA

		Week1			Week2			Week3		
		Δ L	Δ a	Δb	Δ L	Δ a	Δb	Δ L	Δ a	Δb
Tea	**Mean**	-12.11	1.031	0.679	-16.34	0.332	1.652	-16.53	1.555	3.062
	SD	2.416	0. 286	0.342	0.765	0.185	0. 175	0.924	0.233	0.908
	MAX	-9.179	2.271	3.08	-15.111	1.214	3.131	-12.924	4.162	6.37
	MIN	-15.67	-0.556	-1.454	-17.472	-0.844	0.884	-22.158	-0.304	-0.832
	SE	0.730	0.261	0.405	0.231	0.176	0.227	0.873	0.464	0.576
PEPSI	**Mean**	-6.813	0.574	-0.199	-8.712	0.499	0.124	-7.832	0.774	-1.001
	SD	0.344	0.120	0.171	1.495	0.147	0.814	1.873	0.225	0.944
	MAX	-1.982	1.724	1.307	-6.065	1.196	1.562	-2.045	1.698	-0.13
	MIN	-10.308	-0.351	-2.4	-11.901	-0.351	-1.317	-11.766	0.164	-3.051
	SE	0.708	0.187	0.323	0.451	0.135	0.245	0.868	0.158	0.285

Table 3-10: Descriptive statistics of ΔE*values from G&H Company after immersion in PEPSI cola and TEA

		Week1	Week2	Week3
TEA	**Mean**	12.26784	16.45801	19.46178
	SD	2.477743	2.7696	3.261108
	MAX	15.91098	17.73358	25.68906
	MIN	9.223278	15.20983	15.74081

	SE	**0.748563**	**0.232508**	**0.985229**
Pepsi	**Mean**	**6.953848**	**8.778822**	**9.898633**
	SD	**2.337654**	**1.484821**	**1.947203**
	MAX	**10.35077**	**12.02423**	**13.30334**
	MIN	**2.153114**	**6.181838**	**6.247457**
	SE	**0.70624**	**0.448586**	**0.588279**

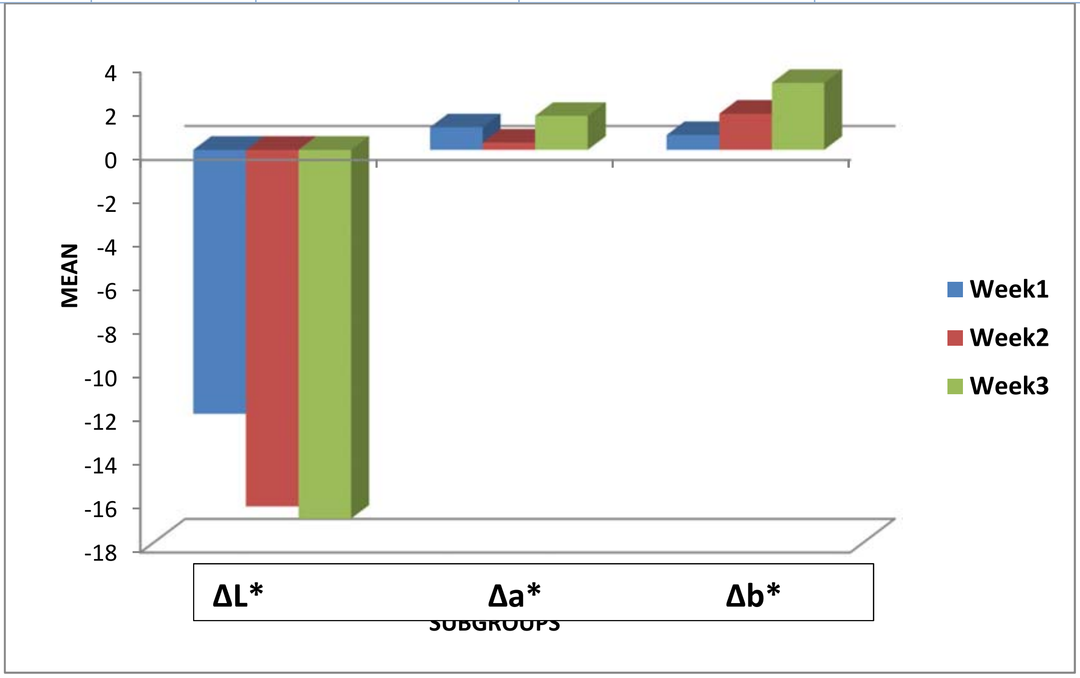

Figure 3-6a: Bar chart shows the mean of ΔL*, Δa*, Δb* of G&H company after immersion in TEA

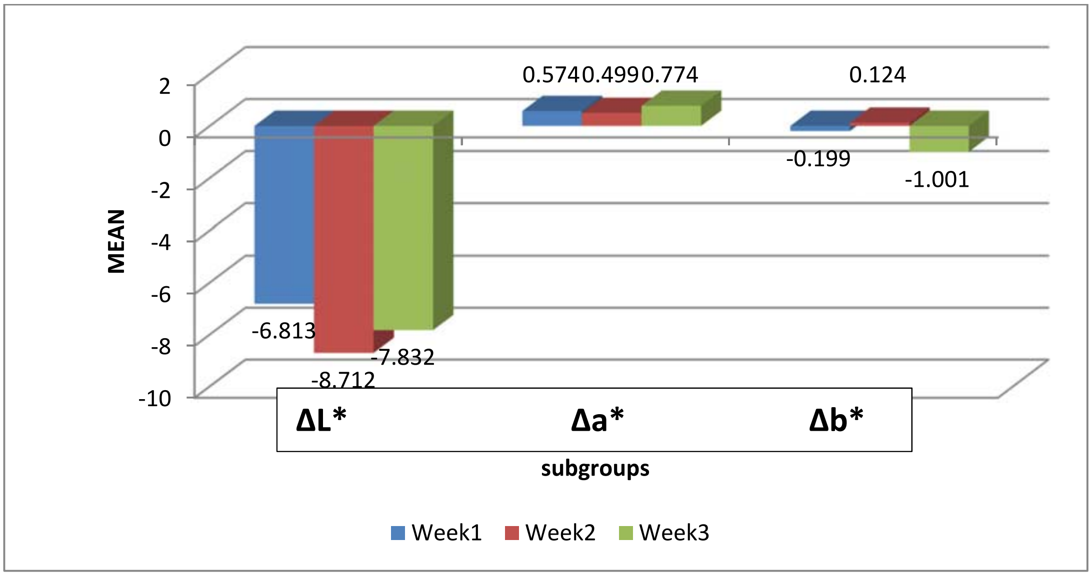

Figure 3-6b: Bar chart shows the mean of ΔL*, Δa*, Δb* of G&H company after immersion in Pepsi cola

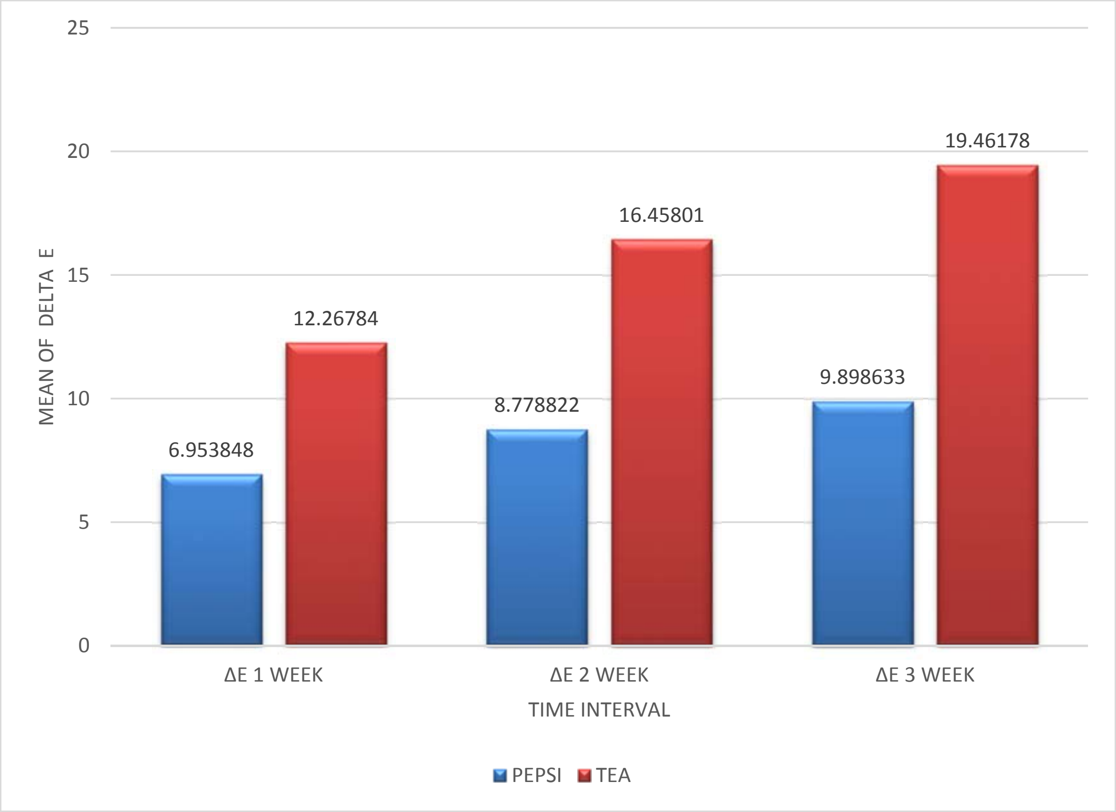

Figure 3-7: Bar chart shows the mean of ΔE* values of Dany company after immersion in TEA and Pepsi cola

3.3.2. Inferential statistics:

Analysis of variance test **(ANOVA)** and least significance difference **(LSD)** test was performed to test any significant difference of **ΔL*, Δa*, Δb*** and **ΔE*** values of esthetic archwires from G&H company after immersion in the staining solution as listed in tables **3-11, 3-12, 3-13** and **3-14 :**

Table 3-11: ANOVA test results for ΔL*, Δa*, Δb* values of G&H company after 3 weeks of immersion in PEPSI cola and TEA

		F-test	P-value	Sig
TEA	ΔL*	13.918	0.00007	HS
	Δa*	3.238	0.049	S
	Δb*	7.168	0.003	S
pepsi	ΔL*	1.694	0.201	NS
	Δa*	0.700	0.504	NS
	Δb*	3.732	0.036	S

DF =59 HS= highly significant @ P<0.01 S= significant @ P<0.05 NS= non-significant @ P>0.05

Table 3-12: LSD test results for ΔL*, Δa*, Δb* values after 3 weeks of G&H company after immersion in PEPSI cola and TEA

		Week1&Week2		Week1&Week3		Week2&Week3	
		P-value	Sig	P-value	Sig	P-value	Sig
TEA	ΔL*	P<0.01	HS	P<0.01	HS	0.578	NS
	Δa*	0.155	NS	0.282	NS	0.016	S
	Δb*	0.135	NS	0.001	S	0.034	S
Pepsi	ΔB	0.450	NS	0.049	S	0.013	S

HS= highly significant @ P<0.01 S= significant @ P<0.05 NS= non-significant @ P>0.05

These tables shows that there is highly significant change on Δ **L*** of the samples after immersion in tea which means that the samples became darker, while it was not significant change after immersion in Pepsi cola.

Table 3-13: ANOVA test results for ΔE* values of G&H company after 3 weeks of immersion in PEPSI cola and TEA

	F-test	P-value	Sig
TEA	**22.51**	**P<0.01**	HS
PEPSI	**5.783**	**0.008**	S

DF =59 HS= highly significant @ P<0.01 S= significant @ P<0.05 NS= non-significant @ P>0.05

Table 3-14: LSD test results for ΔE* of G&H company after 3 weeks of immersion in PEPSI cola and TEA

	Week1&Week2		Week1&Week3		Week2&Week3	
	P-value	**Sig**	**P-value**	**Sig**	**P-value**	**Sig**
TEA	**P<0.01**	**HS**	**P<0.01**	**HS**	**0.009**	**S**
PEPSI	**0.045**	**S**	**0.002**	**S**	**0.210**	**NS**

HS= highly significant @ P<0.01 S= significant @ P<0.05 NS= non-significant @ P>0.05

These tables shows that there was a highly significant change of **ΔE*** after immersion in tea which means great amount of color instability**.**

3.4. Descriptive and inferential statistics of subgroup 3 (Hubit company)

3.4.1. Descriptive statistic:

Means, standard deviation **(SD)**, minimum **(Min)** and maximum **(Max)** values of **ΔL*, Δa*, Δb*** and **ΔE*** of aesthetic archwires from Hubit company after 21 day of immersion in two different staining drinks (Tea and Pepsi cola) listed in tables **3-15 & 3-16** and shown in figures **3-8:a&b and 3-9**:

Table 3-15: Descriptive statistics of ΔL*, Δa*, Δb* values of Hubit Company after 3 weeks of immersion in PEPSI cola and TEA

		Week1			Week2			Week3		
		Δ L	Δ a	Δb	Δ L	Δ a	Δb	Δ L	Δ a	Δb
Tea	**Mean**	-14.54	-7.552	29.85	-15.34	-7.948	31.08	-17.831	-7.556	33.14
	SD	0.938	0.756	2.030	0.983	0.825	1.890	1.347	1.451	5.436
	MAX	-13.115	-5.798	32.177	-13.982	-6.234	33.312	-16.211	-3.163	36.88
	MIN	-16.24	-8.59	24.764	-16.663	-9.385	26.334	-20.707	-8.754	17.09
	SE	0.283	0.228	0.613	0.297	0.249	0.571	0.407	0.438	1.642
PEPSI	**Mean**	-9.306	-0.328	-0.580	-10.76	0.487	-0.580	-11.93	-0.233	-1.544
	SD	5.067	0.455	0.292	1.988	0.328	0.292	0.843	0.031	0.050
	MAX	-0.674	0.487	1.545	-5.056	-1.195	1.545	-10.598	0.509	0.51
	MIN	-17.149	-1.195	-2.799	-12.85	0.1375	-2.799	-13.007	-0.915	-4.021
	SE	1.530	0.137	0. 039	0.600	0.328	0. 239	0.254	0. 013	0. 137

Table 3-16: Descriptive statistics of ΔL*, Δa*, Δb* values of Hubit Company after 3 weeks of immersion in PEPSI cola and TEA

		Week1	Week2	Week3
Tea	**Mean**	34.10161	35.60695	39.6877
	SD	1.552122	1.474225	4.244616
	MAX	35.82935	37.51994	42.89954
	MIN	30.18062	32.14021	27.29712

	SE	**0.468919**	**0.445385**	**1.282361**
PEPSI	**Mean**	**9.514528**	**10.87378**	**11.98322**
	SD	**1.907427**	**1.958102**	**0.882916**
	MAX	**17.29174**	**13.15393**	**13.1764**
	MIN	**1.267182**	**5.322442**	**10.60088**
	SE	**1.482606**	**0.591572**	**0.266742**

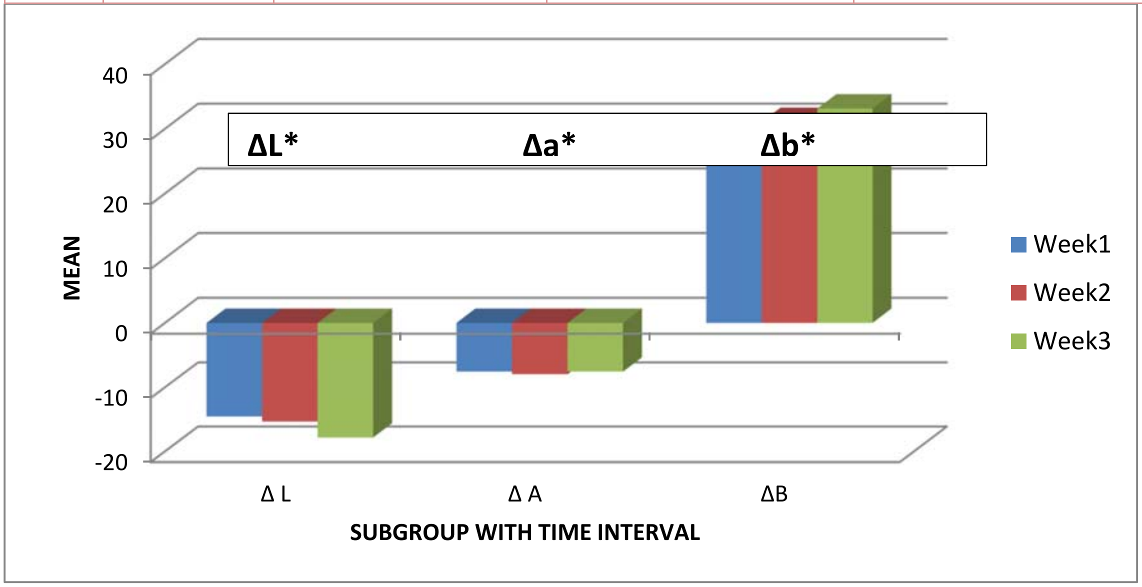

Figure 3-8a: Bar chart shows the mean of ΔL*, Δa*, Δb* of Hubit company after immersion in Tea

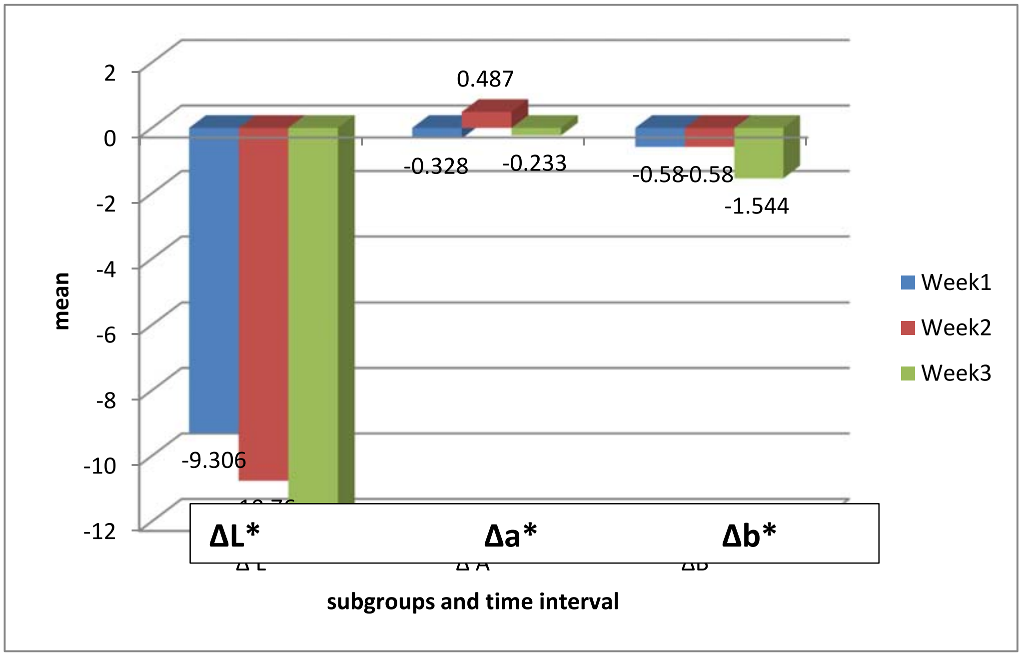

Figure 3-8b: Bar chart shows the mean of ΔL*, Δa*, Δb* of Hubit company after immersion in Pepsi cola

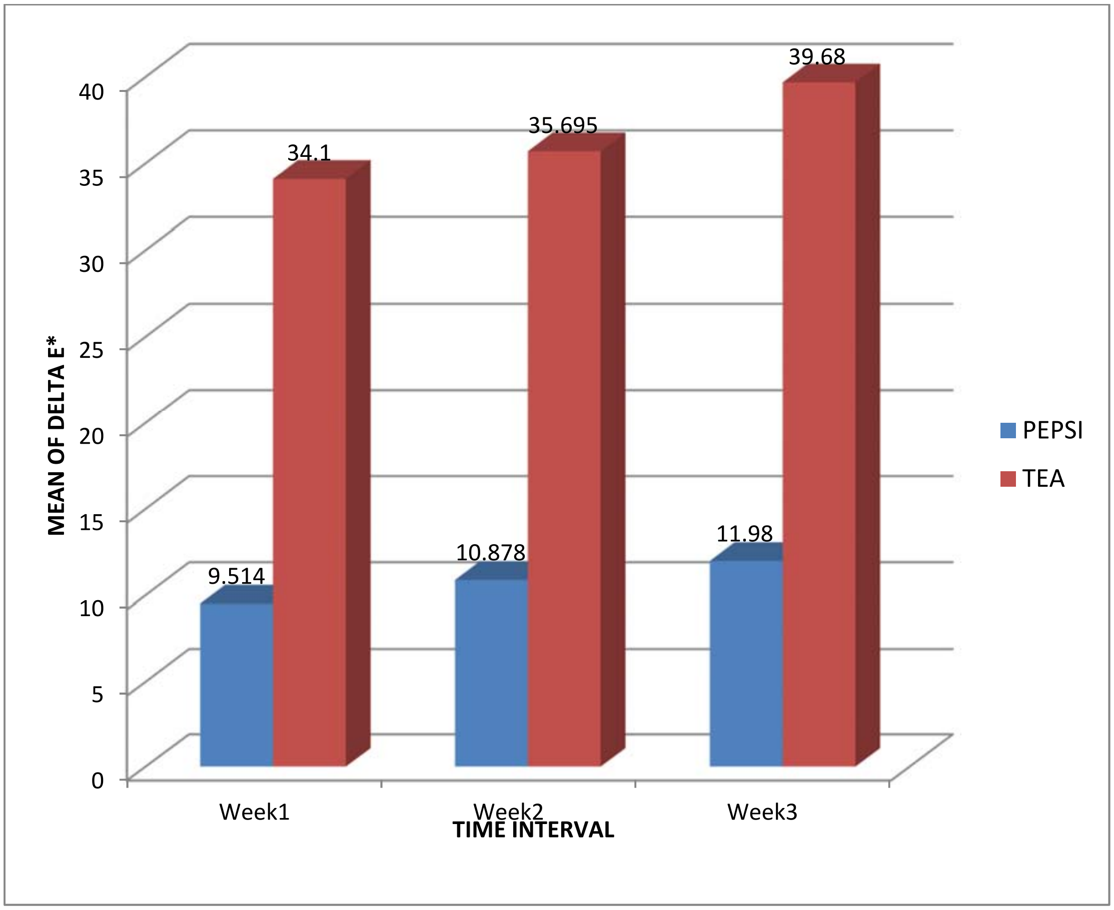

Figure 3-9: Bar chart shows the mean of ΔE* values of Hubit company after immersion in TEA and Pepsi cola

3.4.2. Inferential statistics:

Analysis of variance test **(ANOVA)** and Least significance difference **(LSD)** test was performed to test any significant difference of **ΔL*, Δa*, Δb*** and **ΔE*** values of esthetic archwires from Hubit company after immersion in the staining solution as listed in tables **3-17, 3-18, 3-19** and **3-20:**

Table 3-17: ANOVA test results for ΔL*, Δa*, Δb* values of Hubit company after 3 weeks of immersion in PEPSI cola and TEA

		F-test	P-value	Sig
Tea	**ΔL***	**24.035**	**P<0.01**	**HS**
	Δa*	**0.463**	**0.634**	**NS**
	Δb*	**2.235**	**0.049**	**NS**
PEPSI	**ΔL***	**1.712**	**0.198**	**NS**
	Δa*	**0.153**	**0.859**	**NS**
	Δb*	**2.092**	**0.141**	**NS**

DF =59 HS= highly significant @ P<0.01 S= significant @ P<0.05 NS= non-significant @ P>0.05

Table 3-18: LSD test results for ΔL*, Δa*, Δb* values of Hubit company after 3 weeks of immersion in PEPSI cola and TEA

		Week1&Week2		Week1&Week3		Week2&Week3	
		P-value	**Sig**	**P-value**	**Sig**	**P-value**	**Sig**
TEA	Δ L	**0.115**	**NS**	**P<0.01**	**HS**	**P<0.01**	**HS**

DF =59 HS= highly significant @ P<0.01 S= significant @ P<0.05 NS= non-significant @ P>0.05

These tables shows that there is highly significant change on Δ **L*** of the samples after immersion in tea which means that the samples became darker, while it was not significantly changed after immersion in Pepsi cola.

Table 3-19: ANOVA test results for ΔE* values of Hubit company after immersion f 3 weeks in PEPSI cola and TEA

	F-test	P-value	Sig
TEA	**11.09**	**P<0.01**	HS
PEPSI	**1.598**	**0.209**	NS

DF =59 HS= highly significant @ P<0.01 S= significant @ P<0.05 NS= non-significant @ P>0.05

Table 3-20: LSD test results for ΔE* values for all time interval of Hubit company after immersion in PEPSI cola and TEA

	Week1&Week2		Week1&Week3		Week2&Week3	
	P-value	**Sig**	**P-value**	**Sig**	**P-value**	**Sig**
TEA	**0.230**	**NS**	**P<0.01**	**HS**	**0.002**	**S**

HS= highly significant @ P<0.01 S= significant @ P<0.05 NS= non-significant @ P>0.05

These tables shows that there was a highly significant change of **ΔE*** after immersion in tea which means great amount of color instability**.**

3.5. Descriptive and inferential statistics of subgroup 4 (Orthotechnology company)

3.5.1. Descriptive statistic:

Means, standard deviation **(SD)**, minimum **(Min)** and maximum **(Max)** values of **ΔL*, Δa*, Δb*** and **ΔE*** of aesthetic archwires from orthotechnology company after all time intervals in two different staining drinks (Tea and Pepsi cola) listed in tables **3-21, 3-22** and shown in figures **3-10: a &b and 3-11**:

Table 3-21: Descriptive statistics of ΔL*, Δa*, Δb* values of Orthotechnology Company after 3 weeks of immersion in PEPSI cola and TEA

		Week1			Week2			Week3		
		Δ L	Δ a	Δb	Δ L	Δ a	Δb	Δ L	Δ a	Δb
Tea	**Mean**	-7.710	0.325	4.216	-8.842	0.557	1.536	-9.817	-0.029	1.056
	SD	3.1970	0.733	0.992	2.064	2.535	0.824	0.263	0.008	0,062
	MAX	-1.094	4.891	8.107	-14.10	6.897	4.107	-4.976	1.494	7.765
	MIN	-12.32	-1.975	-2.705	-20.37	-1.829	-1.745	-16.951	-1.801	-2.064
	SE	0.965	0.253	0.093	0.623	0.766	0.155	1.288	0.034	0.486
PEPSI	**Mean**	0.007	-0.110	1.4267	-1.989	-0.126	-1.654	-0.855	-1.251	-2.163
	SD	0.089	0.074	0.782	0.268	0.481	0.012	0.137	0.915	0.153
	MAX	1.883	1.155	3.7642	0.207	0.925	0.491	3.3655	-0.004	5.0452
	MIN	-1.977	-1.2773	-1.93	-4.246	-0.841	-3.446	-3.958	-2.7903	-2.798

	SE	**0.127**	**0.023**	**0.358**	**0.338**	**0.145**	**0.035**	**0.045**	**0.276**	**0.650**

Table 3-22: Descriptive statistics of ΔE* values from Orthotechnology Company after immersion in PEPSI cola and TEA

		Week1	Week2	Week3
TEA	**Mean**	**9.391438**	**16.8079**	**17.225**
	SD	**3.361046**	**2.060493**	**4.218684**
	MAX	**14.19059**	**20.456**	**19.21406**
	MIN	**3.212598**	**14.38124**	**3.618221**
	SE	**1.015422**	**0.622505**	**1.274527**
PEPSI	**Mean**	**2.334233**	**2.793606**	**3.256538**
	SD	**0.020417**	**0.824213**	**0.737079**
	MAX	**4.398453**	**4.568541**	**4.608011**
	MI	[illegible]	[illegible]	**2.119941**
	SE	**0.108283**	**0.249007**	**0.222682**

ΔL* **Δa*** **Δb***

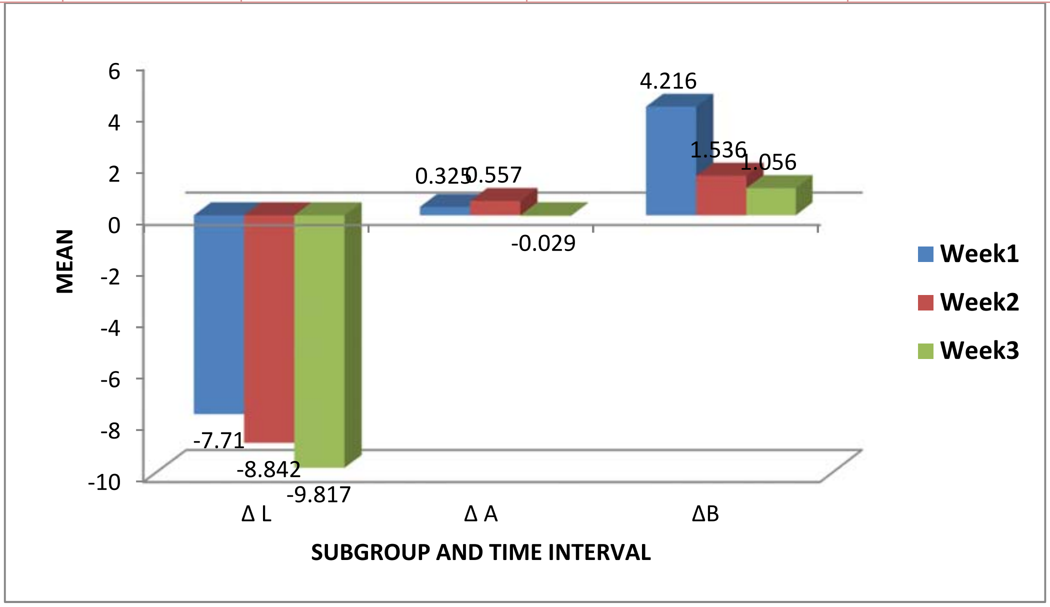

Figure 3-10.a: Bar chart shows the mean of ΔL*, Δa*, Δb* of Orthotechnology company after immersion in Tea

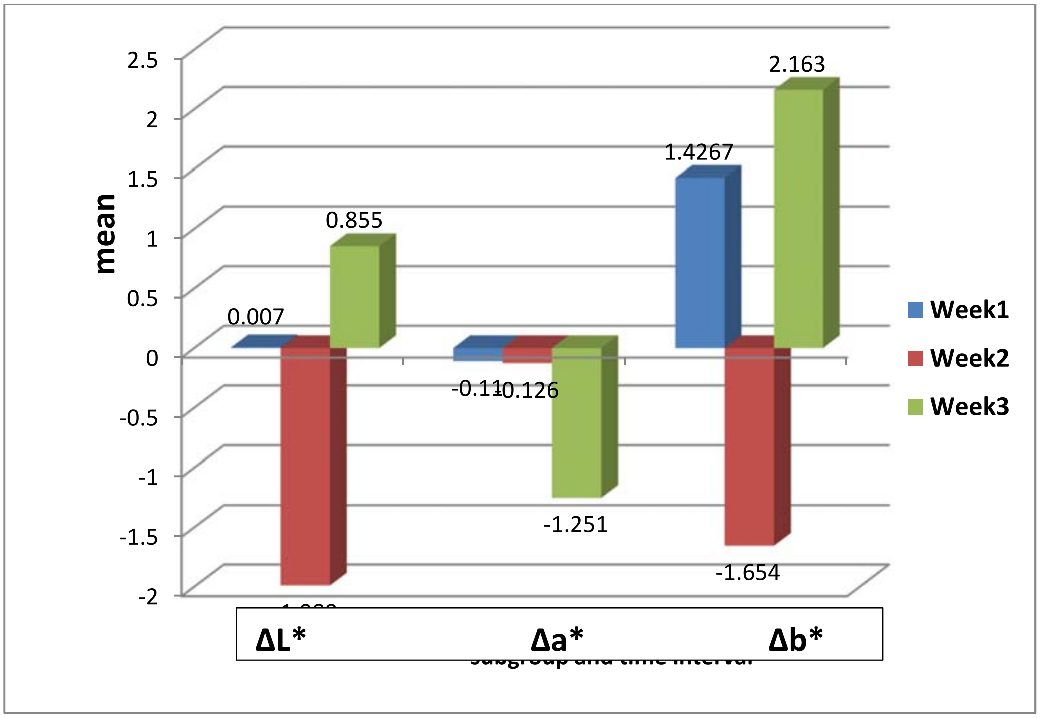

Figure 3-10.b: Bar chart shows the mean of ΔL*, Δa*, Δb* of Orthotechnology company after immersion in pepsi cola

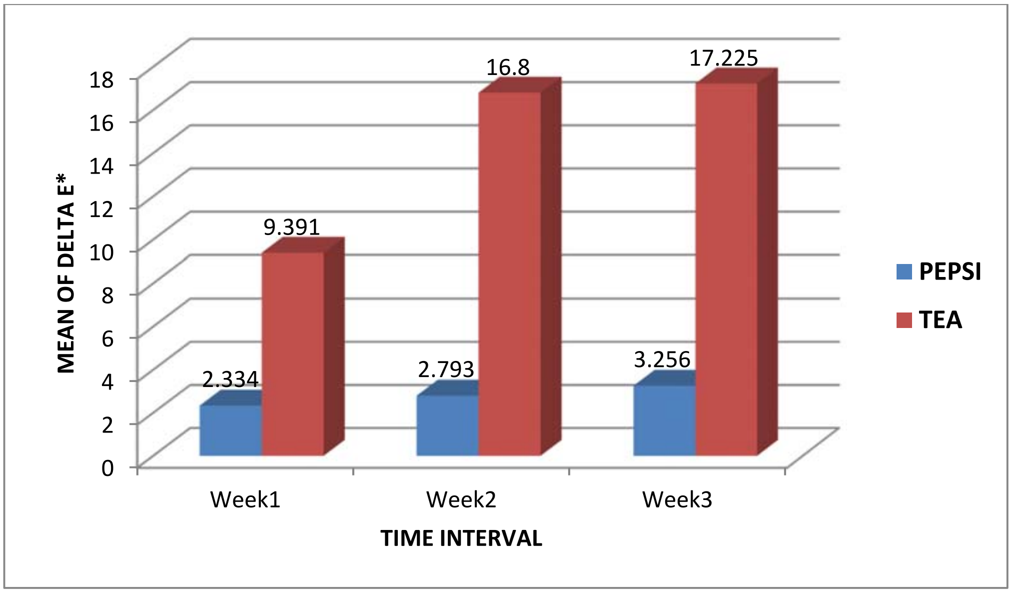

Figure 3-11: Bar chart shows the mean of ΔE of Orthotechnology Company after immersion in Tea and Pepsi cola

3.5.2. Inferential statistics:

Analysis of variance test **(ANOVA)** and least significance difference **(LSD)** test was performed to test any significant difference of **ΔL*, Δa*, Δb*** and **ΔE*** values of esthetic archwires from Orthotechnology company after immersion in the staining solution as listed in tables **3-23, 3-24, 3-25** and **3-26:**

Table (3-23) ANOVA test results for ΔL*, Δa*, Δb* values of Orthotechnology company after 3 weeks of immersion in PEPSI cola and TEA

		F-test	P-value	Sig
Tea	**ΔL***	**19.029**	**P<0.01**	**HS**
	Δa*	**0.251**	**0.780**	**NS**
	Δb*	**4.250**	**0.024**	**S**
PEPSI	**ΔL***	**9.161**	**P<0.01**	**HS**
	Δa*	**8.426**	**P<0.01**	**HS**
	Δb*	**13.919**	**P<0.01**	**HS**

DF =59 HS= highly significant @ P<0.01 S= significant @ P<0.05 NS= non-significant @ P>0.05

Table 3-24: LSD test results for ΔL*, Δa*, Δb* values for all time interval of Orthotechnology company after immersion in PEPSI cola and TEA

		Week1&Week2		Week1&Week3		Week2&Week3	
		P-value	**Sig**	**P-value**	**Sig**	**P-value**	**Sig**
Tea	**ΔL***	**P<0.01**	**HS**	**0.163**	**NS**	**P<0.01**	**HS**
	Δb*	**0.029**	**S**	**0.011**	**S**	**0.684**	**NS**
PEP	**ΔL***	**0.006**	**S**	**0.224**	**NS**	**P<0.01**	**HS**

HS= highly significant @ P<0.01 S= significant @ P<0.05 NS= non-significant @ P>0.05

	Δa*	**0.962**	**NS**	**P<0.01**	**HS**	**P<0.01**	**HS**
	Δb*	**P<0.01**	**HS**	**0.345**	**NS**	**P<0.01**	**HS**

These tables shows that there is highly significant change on Δ **L*** of the samples after immersion in both tea and Pepsi cola which means that the samples became darker.

Table 3-25: ANOVA test results for ΔE* values for Orthotechnology company after 3 weeks of immersion in PEPSI cola and TEA

DF =59 HS= highly significant @ P<0.01 S= significant @ P<0.05 NS= non-significant @ P>0.05

	F-test	P-value	Sig
TEA	**13.394**	**P<0.01**	**HS**
PEPSI	**2.818**	**0.049**	**S**

Table 3-26: LSD test results for ΔE* values for Orthotechnology company after 3 weeks of immersion in PEPSI cola and TEA

	Week1&Week2		Week1&Week3		Week2&Week3	
	P-value	**Sig**	**P-value**	**Sig**	**P-value**	**Sig**
TEA	**P<0.01**	**HS**	**0.221**	**NS**	**P<0.01**	**HS**
PEPSI	**0.246**	**NS**	**0.024**	**NS**	**0.243**	**NS**

DF =59 HS= highly significant @ P<0.01 S= significant @ P<0.05 NS= non-significant @ P>0.05

These tables shows that there was a highly significant change of **ΔE*** after immersion in tea which means great amount of color instability.

3.6. Amount of color change to a clinical environment:

When the ΔE of all the companies is collected, the data were converted to National Bureau of Standards (NBS) units **as** follows: **(Nimeroff, 1968)**

$$\textbf{NBS units} = \Delta E \times 0.92$$

And the result is shown in table **(3-27):**

Table 3-27: Amount of color change according to National Bureau of Standards (NBS) units for all time interval

Where are*:

SUBGROUP		1ST WEEK		2ND WEEK		3RD WEEK	
		NBS UNIT	Color change	NBS UNIT	Color change	NBS UNIT	Color change
Tea	1	8.9654	Much	12.88184	Very much	12.93152	Very much
	2	11.28564	Much	15.14136	Very much	17.90412	Very much
	3	31.37292	Very much	32.75752	Very much	36.51204	Very much
	4	8.63972	Much	15.46336	Very much	15.847	Very much
Pepsi	1	3.65424	Appreciable	4.31112	Appreciable	6.29924	Much
	2	6.39676	Much	8.07576	Much	9.10616	Much
	3	8.75288	Much	10.00316	Much	11.02436	Much
	4	2.14728	Noticeable	2.56956	Noticeable	2.99552	Noticeable

Very much: 12.0+ in NBS units

Much: 12.0- 6.0 in NBS units

Appreciable: 6.0 - 3.0 in NBS units

Noticeable: 3.0 - 1.5 in NBS units

Chapter four

Discussion

4.1. The need for the study:

Esthetic is the chief requirement of all orthodontic patient, so any staining or discoloration or change in esthetic of patient will affect the cooperation and acceptance to his treatment. The demand for esthetic orthodontic appliances is increasing, and the development of materials that present an acceptable esthetics for the patients and an adequate clinical performance for clinicians is needed. This demand has led to the development of orthodontic appliances with acceptable esthetics both for patients and clinicians. **(Kaphoor and Sundareswaran, 2012),** ideally, the color of esthetic archwires should match that of natural teeth and esthetic brackets. However, the colors of natural teeth vary according to the color measurement protocols used and also by race, gender, and age. **(Bolt *et al*., 1994; Li y, 2009).**

Coating improves esthetics but has some disadvantages, the color tends to change with time; **proffit in (2000)** describe the coat as “un-durable”, like other esthetic orthodontic products, there are internal and external causes for the discoloration of esthetic archwires.

External discoloration can be caused by food dyes and colored mouth rinses, the type of coating material and its surface roughness play decisive roles in the extent of the discoloration caused by diverse substances. The amount of color change can be influenced by a number of factors, including oral hygiene and water absorption **(Faltermeier *et al*., 2008).**

4.2. Spectrophotometer measurement:

Since instrumental measurements eliminate the subjective interpretation of visual color comparison, spectrophotometers or colorimeters are used instead of visual evaluation **(Buyukyilmuz and Ruyter, 1994)**. Spectrophotometer has been used in many previous studies to measure color change **(ΔE*)** by comparing the values of L*a*b* before and after treatment according to CIE **Lab** system by following formula **(Gaintantzopnulou *el al*., 2005):**

$$\boldsymbol{\Delta E} * = (\Delta \boldsymbol{L}^{*\mathbf{2}} + \Delta \boldsymbol{a}^{*\mathbf{2}} + \Delta \boldsymbol{b}^{*\mathbf{2}})^{\mathbf{1l2}}$$

The value of ΔE* represents relative: colors changes that an observer might report for the materials after immersion. Thus ΔE* is more meaningful than the individual L*, a*, b* values **(Yannikakis *et al*., I998)**.

Because the ability of the human eye to appreciate differences in color differs from individual to individual (as it is a combination of eye characteristics and skill of the operator), three different intervals were used for distinguishing color differences. Values of Δ E* < l, were regarded as not appreciable (Perceptible) by the human eye. If 3.3 > Δ E*> l, this color difference is appreciable by skillful operator but considered clinically acceptable. Whilst values of Δ E* > 3.3 are appreciable by non-skilled persons and considered clinically unacceptable **(Um and Ruyters, 1991; Diab *et al*., 2007).**

Many authors **(Stober *et al*., 2001; Eliades *et al*., 2004; Koksal and Dikbas, 2008)** have used ΔE* values to evaluate the ‘‘perceptibility’’ of color differences. However, it is noteworthy that the criteria for perceptibility adopted by each author were different.

To counter such differences and disagreements in the criteria used, the NBS rating system is frequently used to determine the degree of color difference, since it offers absolute criteria by which ΔE* values can be converted to definitions with clinical significance **.(Nimeroff, 1968; Koksal and Dikbas, 2008)**

4.3. The effect of staining solution type:

The present study evaluated the effects of two famous drinks that Consumed daily by the patient **(which are Tea and Pepsi cola)** on the color stability of aesthetic archwires from four commercially present coated archwires that coated by two different coating material which are Epoxy resin **(Orthotechnology company and G&H company)** and poly-tetra-flouro-ethylene (Teflon) material **(Dany company and Hubit company).**

Both types of tested solutions cause a color change of the coating archwires but in variable degree. The most staining solution was the Tea for all the types of the coated archwires.

The highest **ΔE*** for the Tea solution was for the **Hubit** company **(ΔE*= 39.687)**; followed by **G&H** company **(ΔE*=19.461)**, then by **Orthotechnology** company **(ΔE*=17.225),** then by **Dany** company **(ΔE*= 14.056);** all in 3rd week of immersion.

So the color change occurred by the tea solution was very noticeable and appreciable by non-skilled persons and considered clinically unacceptable. For the **Pepsi Cola** the result was variable; it was much less staining than the tea solution. The highest **ΔE*** was also for **Hubit** company **(ΔE*= 11.983)**; while for **G&H** company **(ΔE*=9.898)**, followed by **Dany** company **(ΔE*= 6.847)**; then the **Orthotechnology** company **(ΔE*= 3.256)**; all in the 3rd week of immersion.

The samples treated by the Tea solution were appeared darker compared with the samples treated by the Pepsi cola solution by the naked eyes. The color change occurred by the Pepsi cola solution was noticeable and appreciable by non-skilled persons and considered clinically unacceptable for all the companies (except for the **Orthotechnology** company where the change in color was appreciable only by skillful operator but considered clinically acceptable); but still much lighter and acceptable than the color change occurred due to Tea solution.

This results are agree with **Da Silva *et al.* in 2013** that evaluated the color stability of six aesthetic archwires at different time periods and found that all the esthetic archwires assessed showed noticeable color change after 21 days. The results also are agree with **Mohammed I. in 2013** that evaluate and compare the color stability of four aesthetic archwires at different time periods (7th ,14th , & 21st day) of immersion in the staining solution

.4.4. Comparison between different companies:

Color changes were characterized using the **CIE L*a*b*** color space. The **CIE L*a*b*** color space is currently one of the most popular and widely used systems of color measurement, and it is well suited for the determination of small color differences. **(Da Silva *et al.*, 2013)**

When compared the **L*, a*** and **b*** values of each company, the results found that means of **L*** values of all companies were decrease after immersion in both treatment solutions (**ΔL*** negative), because all of the specimens became darker after immersion in solutions, except for the **Orthotechnology** company after immersion on Pepsi cola which had **ΔL*** positive .

The highest negative **ΔL*** was for the **Hubit** company after immersion in tea **(ΔL*=-17.831);** that's mean it's became the darker one among all the other types. And after immersion in Pepsi cola **(ΔL*= -11.933**); also very high significant change in its **Δa*** that become negative **(Δa*= -7.556)** and **Δb*** which become positive **(Δb*= 33.149)** after immersion in tea that means the sample become greener yellower.

It also had the highest **ΔE*(39.687),** which mean that the sample changed completely to another color. There was non-significant change in **Δa*** and **Δb*** after immersion in **Pepsi cola.**

The second highest significant change for **ΔL*** was for the **G&H** company where **(ΔL*= -16.903)** after immersion in tea and **(ΔL*= -7.832)** after immersion in Pepsi cola. While the **Δa*** was positive **(Δa*= 1.555)** and **Δb*** was **(Δb* =3.062)** positive after immersion in tea which means that the samples became redder yellow; but **Δa*** was positive **(Δa* = 0.774)** and **Δb*** was negative **(Δb*= -1.001)** after immersion in Pepsi cola, which means that the samples became redder blue.

Next in the change in the brightness (**ΔL***) was the **Dany** company where the **ΔL*** was **(- 13,561)** after immersion in tea and **(-6.578)** after immersion in Pepsi cola. While **Δa*** was positive on both tea **(2.164)** and Pepsi cola **(0.014)** which is non-significant change.

Δb* was also positive on both the tea **(Δb*=1.19)** and on Pepsi cola **(Δb*=0.721)** which mean that the samples became redder yellow.

The least amount of change in the brightness was in the **Orthotechnology** company where **ΔL*** was **(-9.817)** after immersion on tea and **(0.855)** after immersion in Pepsi cola which mean that the samples became lighter but the change was not significant, while for **Δa***, it was negative on both tea **(-0.029)** and Pepsi cola **(-1.251)** and the **Δb*** was positive on tea **(1.056)** and on Pepsi cola **(2.163)** which means that the samples were greener yellow.

When compared **ΔE*** of all the companies , we found that the highest change on color occurred at the end of the 3rd week , which means that it increased with time

, but the greater change from the basic measurement occur on the 1st week , then the change in color progress in slower rate .

4.5. Clinical consideration:

The present study shows that there are difference in the amount of color change of the difference aesthetic archwires from different companies under the same circumstances, this may be related to the chemical and physical composition of the aesthetic archwires which need further investigations to each company to discover out the cause of this variation. The difference between the two staining solution (tea and Pepsi cola) is related to the composition of these solution. There is difference in the caffeine content between the two solutions, each 8 oz. (237 ml) of Black tea contain about 14-70 mg of caffeine while each 12 oz. (355 ml) of Pepsi cola contain about just 32-39 mg of caffeine **(McCusker *et al*., 2003; McCusker *et al*., 2006a; McCusker *et al*., 2006b; Chin *et al*., 2008; Heckman *et al*., 2010).**

The Pepsi cola contain also carbonated water (soda), Phosphoric acid, citric acid that may have some cleaning action , while the tea contain some precipitation from the tea leaves that will increase the staining effect **(Neeraj, 2007; Hammer *et al*., 2012).** So according to the result of this study , its suitable to advice the patient to minimize drinking of these staining solution to keep the aesthetic appliance as bright and not stained as possible**.**

4.6. Limitations of the study:

The staining inside the patient mouth (in vivo) differs from that found in vitro because there are other factor play role in staining like:

- Bacterial deposit on the archwires.

- Surface roughness from abrasion due to occlusion, eating a scratching from cleaning of the appliance.
- The effect of salivary mucins and proteins (washing effect of saliva).

Conclusions & suggestions

5.1. Conclusions:

Under the condition of the present study the following conclusion could be derived:

1. Both solution **(tea and Pepsi cola)** caused color change in variable degree for all companies; the tea caused a larger amount of color change than Pepsi cola, with highly significant change for all companies.
2. **Hubit** Company has the highest **ΔE*** after immersion in tea and Pepsi cola which means that it's the less color stable aesthetic archwires.
3. **Orthotechnology** company has the lowest **ΔE*** after immersion in Pepsi cola which means that it's the most color stable aesthetic archwires under this condition.
4. **Dany** company has the lowest **ΔE*** after immersion in tea which means that it's the most color stable aesthetic archwires under this condition.
5. The amount of color change increased with time, but the great amount of change occur in the first week then the staining progress in slower rate.

5.2. Suggestions:

1. Use different staining solution such juices and coffee.
2. Study the effect of spices on the color stability of the aesthetic archwires.
3. Study the effect of the staining solution on the aesthetic archwires in vivo (inside the oral cavity).
4. Use another types of aesthetic archwires (from different companies).
5. Study the color stability of NiTi coated archwires.
6. Study the effect of mouthwashes on the color stability of aesthetic archwires.
7. Study the effect of scratching along with staining solutions on the color stability of the aesthetic archwires.
8. Study the color stability of the aesthetic archwires after immersion for less time in the staining solutions.
9. Do further investigation on aesthetic archwires from **Hubit** company to discover out the cause behind it great amount of color instability.

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Appendix I: CIE x-, y-, z- for the 1976 CIE standard observer and standard illuminants D65 tabulated at 10 ηm intervals **(sharma, 2003)**

$\lambda(\eta m)$	$\bar{X}\lambda$	$\bar{Y}\lambda$	$\bar{Z}\lambda$	I D65(λ)
400	0.0143	0.0004	0.0679	82.7549
410	0.0435	0.0012	0.2074	91.486
420	0.1344	0.004	0.6456	93.4318
430	0.2839	0.0116	1.3856	86.6823
440	0.3483	0.023	1.7471	104.865
450	0.3362	0.038	1.7721	117.008
460	0.2908	0.06	1.6692	117.812
470	0.1954	0.91	1.2876	114.861
480	0.0956	0.139	0.813	115.923
490	0.032	0.208	0.4652	108.811
500	0.0049	0.323	0.272	109.354
510	0.0093	0.503	0.1582	107.802
520	0.0633	0.71	0.0782	104.79
530	0.1655	0.862	0.0422	107.689
540	0.2904	0.954	0.0203	104.405
550	0.4334	0.995	0.0087	104.046
560	0.5945	0.995	0.0039	100
570	0.7621	0.952	0.0021	96.3342
580	0.9163	0.87	0.0017	95.788
590	1.0263	0.757	0.0011	88.6856
600	1.0622	0.631	0.0008	90.0062
610	1.0026	0.503	0.0003	89.991
620	0.8544	0.381	0.0002	87.6987
630	0.6424	0.265	0	83.2886
640	0.4479	0.175	0	83.6992
650	0.2835	0.107	0	80.0268
660	0.1649	0.61	0	80.2146
670	0.0874	0.032	0	82.2778
680	0.0468	0.017	0	78.2842
690	0.0227	0.0082	0	69.7213
700	0.0114	0.0041	0	71.6091

Appendix II: Δ L*, Δ a*, Δ b* values of all companies at the end of 3rd week after immersion in tea.

No.	Δ L*, Δ a*, Δ b* values of all companies											
	Dany			G&H			Hubit			Orthotechnology		
	Δ L*	Δ a*	Δ b*	Δ L*	Δ a*	Δ b*	Δ L*	Δ a*	Δ b*	Δ L*	Δ a*	Δ b*
1	-15.894	3.19	5.287	-15.744	-0.009	-0.832	-20.707	-8.754	33.347	-9.709	-0.229	0.595
2	-14.339	0.887	2.097	-15.002	-0.304	2.375	-18.227	-7.381	36.81	-11,89	-1.262	0.208
3	-9.305	1.03	-0.636	-14.064	4.162	2.825	-16.606	-8.387	36.886	-12.095	0.29	1.371
4	-16.205	-1.564	3.58	-12.924	1.093	2.85	-17.18	-7.586	35.575	-11.563	1.494	-2.064
5	-15.088	1.5987	-6.53	-15.786	1.267	1.295	-18.04	-8.196	34.907	-8.757	-0.727	-1.278
6	-18.319	5.382	5.055	-22.145	3.879	6.37	-17.364	-8.425	35.86	-8.218	0.126	-0.4158
7	-12.03	1.572	-0.979	-17.784	0.133	3.767	-16.929	-8.096	35.945	-8.78	0.828	-0.152
8	-11.249	-1.577	1.265	-17.533	1.323	3.593	-16.211	-8.037	35.915	-16.951	1.257	5.781
9	-11.554	1.398	1.903	-17.986	1.106	1.804	-18.321	-7.438	31.487	-6.24	-0.902	0.316
10	-11.456	0.887	1.509	-14.805	0.765	3.895	-16.654	-7.656	30.812	-10.77	-1.801	-0.505
mean	-13.561	2.164	1.190	-16.90	1.555	3.0626	-17.83	-7.556	33.149	-9.81	-0.029	1.056

Appendix III: Δ L*, Δ a*, Δ b* values of all companies at the end of 3rd week after immersion in Pepsi cola

No.	Δ L*, Δ a*, Δ b* values of all companies											
	Dany			G&H			Hubit			Orthotechnology		
	Δ L*	Δ a*	Δ b*	Δ L*	Δ a*	Δ b*	Δ L*	Δ a*	Δ b*	Δ L*	Δ a*	Δ b*
1	-8.1	-0.337	2.159	-7.21	1.542	-0.987	-11.058	0.436	-1.19	-3.958	-0.19	0.515
2	-8.471	-0.506	2.654	-8.154	1.698	-0.386	-11.109	-0.5	-1.804	-0.66	-0.004	0.001
3	-7.663	0.002	2.279	-7.402	0.165	-0.38	-12.936	-0.426	-4.021	-2.232	-0.144	-2.798
4	-6.623	-0.014	1.135	-11.766	0.523	-0.224	-11.731	-0.161	-1.683	1.886	-1.4	1.73
5	-5.3	-0.342	1.028	-9.574	0.318	-3.051	-11.373	-0.16	-1.683	1.478	-0.9045	2.461
6	-5.425	-0.857	0.295	-10.135	0.84	-1.19	-13.007	0.509	-1.448	0.8545	-1.0958	2.0167
7	-4.523	0.347	-2.023	-2.045	0.164	-0.386	-12.896	-0.673	-1.32	0.515	-0.7891	3.3914
8	-7.643	0.181	1.793	-9.539	0.338	-0.832	-10.598	0.001	-1.081	0.9735	-2.3564	3.5761
9	-7.362	-0.177	1.662	-2.602	0.865	-0.13	-12.918	-0.649	-2.428	2.566	-1.8577	3.3608
10	-5.742	1.364	-2.746	-9.354	1.379	-2.723	-12.101	-0.025	0.51	0.3655	-2.237	4.5035
mean	-6.57	0.014	0.721	-7.832	0.774	-1.0	-11.93	-0.233	-1.544	-1.251	0.915	2.16

الخلاصة

اقيمت هذه الدراسة المختبرية لتقييم تاثير اثنين من السوائل الملونة والتي هي (الشاي الاسود والبيبسي كولا) على الاستقرار والثبات اللوني لاربعة من الاسلاك التقويمية التجميلية من اربع شركات مختلفة .

الاعداد الكلية للعينات كانت ثمانية واربعين شريط , كل شريط يتكون من عشرة اسلاك تقويمية تجميلية , تم تعرضها الى قياسات استقرار اللون وقسمت كلاتي :

- **مجموعة أ** : تتكون من اربعة وعشرين شريط (اثنتا عشر شريط اعدت لغرض الغمر في الشاي الاسود واثنتا عشر شريط اعدت للغمر في الماء المقطر لغرض استخدامها كمرجع مقارنه .
- **مجموعة ب** : تتكون من اربعة وعشرين شريط (اثنتا عشر شريط اعدت لغرض الغمر في البيبسي كولا و اثنتا عشر شريط اعدت للغمر في الماء المقطر لغرض استخدامها كمرجع للمقارنة .

كل مجموعة قسمت بحسب وقت الغمر في السائل الملون الى :

- مجموعة الوقت1: اربعة شريط تغمر لمدة اسبوع واحد.
- مجموعة الوقت2: اربعة شريط تغمر لمدة اسبوعين.
- مجموعة الوقت3: اربعة شريط تغمر لمدة ثلاثه اسابيع .
- مجموعة المرجع : اثنتا عشر شريط تغمر بالماء المقطر لمدة مماثلة للمجموعة المقابلة .

كل مجموعة فرعية تحتوي على شريط متكون من عشرة اسلاك تقومية تجميلية من كل شركة , غمرت الشرائط في المحاليل الملونة وحفظت بدرجه 37 سيليزية ثم تعرضت لقياسات درجة الاستقرار والثبات اللوني بواسطه جهاز فحص الطيف اللوني الموصل بالكومبيوتر , تم حساب النتائج حسب المنظمه العالميه للاضاءة , لعام 1976وقد حللت البيانات الناتجه احصائيا باستخدام اختبار تحليل التباين (ANOVA) وكذلك اختبار الفرق المعنوي (LSD) .

كشفت النتائج ان كلا من السوائل الملونة (الشاي الاسود والبيبسي كولا) تسبب تغيرا لونيا للاسلاك التقويميه التجميلية بدرجات مختلفة , وكذلك نسبه التغير باللون تزداد مع الوقت . حيث ان الشاي الاسود يسبب تغيرا لونيا محسوس بصريا للاسلاك التقويميه التجميليه وهو تغير اعلى من الذي يسببه البيبسي كولا,النسبه الاعلى للتغير اللوني كان للاسلاك التقويميه التجميلية من شركه (Hubit) بعد غمرها بالشاي الاسود , حيث تم تحولها الى اللون الاصفر بينما كانت النسبه الاوطئ للتغير باللون للاسلاك التقويميه التجميليه من شركه (Orthotechnology) بعد غمرها بالبيبسي كولا.

الاستقرار اللوني للاسلاك التقويمية التجميلية المختلفة
(دراسة مختبرية)

رسالة مقدمة الى كلية طب الاسنان – جامعة بغداد كجزء من
متطلبات نيل درجة الماجستير في تقويم الاسنان

من قبل

زينب ثائر نوري
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العراق – بغداد

ذي الحجة 1435 هجري **تشرين الاول 2014 ميلادي**