COLOR STABILITY OF CERAMIC BRACKETS IMMERSED IN ARTIFICIAL SALIVA AND A POTENTIALLY STAINING HEALTH DRINK SOLUTION - AN INVITRO STUDY

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INTRODUCTION

Webster has defined the term esthetics as “appreciative of, responsive to or zealous about the beautiful” [24] .The adult patients seeking the orthodontic therapy have increased enormously due to increase in the demand for esthetics. The esthetic demand is not only after the orthodontic therapy but even during the course of treatment. This has resulted in the development of tooth colored or esthetic brackets.

The plastic brackets made of acrylic and polycarbonate was manufactured in the early1970s. They had several disadvantages such as lack of strength, lack of rigidity, poor technical performance, poor long term esthetic stability and ease of deformation [28] . This was replaced by the polycarbonate brackets reinforced with ceramic or fiberglass fillers with metal slots and polyurethane brackets. A few of the problems persisted and this lead to the development of ceramic brackets [24, 28].

The advent of the ceramic brackets in 1980’s had several advantages and provided superior esthetics among the esthetic brackets. The major composition of the ceramic brackets is aluminium oxide or alumina which is available in two forms based on the manufacturing process [22, 9, 3]. There are monocrystalline and polycrystalline varieties in ceramic brackets.

The manufacturing of monocrystalline ceramic brackets is more difficult and expensive. The aluminium oxide particles are melted in a furnace at temperature of 2,100 degree Celsius and allowed to cool slowly to form a single crystal of alumina and the ceramic brackets are milled and cut into its shape. The slot dimensions are provided by the diamond cutting tools and the milled brackets are heat treated to remove the stresses [39, 9].

Polycrystalline ceramic brackets are made up of fused aluminium oxide particles which are blended with a binder. The sintering or molding process is done, in which the mixture is molded and cut into shapes of the brackets and subjected to firing at a temperature of 1,800 degree Celsius to burn out the binder and allow the fusion of the aluminium oxide particles. Diamond cutting tools are used to cut the slot dimensions and the brackets are machined followed by heat treated [39, 9].

There are different manufacturers available in the market for the fabrication of ceramic brackets. Some of them are American orthodontics, Damon, 3M/Unitek, Rocky mountain orthodontics, GAC, TP orthodontics, Lancer orthodontics[9]. Ceramic brackets of different manufacturers have been assessed in most of the studies.

The greatest advantage of the ceramic brackets is their superior esthetics. The ceramic brackets should be transparent enough and good stability to have a better esthetic look, so that it is close to the color of the underlying tooth. Monocrystalline brackets appear more translucent than the polycrystalline ceramic brackets [22, 3, 39].

Monocrystalline brackets have the clear appearance because of the larger grain size and reduced impurities during the manufacturing process whereas the polycrystalline brackets tends to reflect light which causes some degree of opacity due to presence of more impurities during the manufacturing process [34, 29]. The drawback of ceramic brackets is that they are stained by various food solutions, such as tea, coffee, drinks, wine, when exposed to the oral environment.

Discoloration of the ceramic brackets generally occurs by two factors – intrinsic and extrinsic factors [1, 2].

1. Intrinsic factors such as water absorption, composition of bracket matrix, size of the particles.
2. Extrinsic factors such as pigments present in food, beverages, tea, coffee, wine, mouth rinses.

Most of the studies used the above drinks as food solution for the color assessment of the ceramic brackets. In general most of the children and adolescents consume the nutritive health drink rather than other drinks.

Olivera et al [7], Faltermeier et al [2] and Yadav et al [26] had used red wine, coffee, tea, coke and artificial saliva as the staining solutions in their studies. Nutritive health drink powder solution (Boost) is taken as staining solution for this study.

Artificial saliva has been used to imitate the oral environment because it responds to the sample material in the same way as the natural saliva does. Artificial saliva as a medium has been used in several studies by Olivera et al[7]. The artificial saliva which is used in the study is made by B.N laboratory, Mangalore.

Olivera et al, Faltermeier et al and Yadav et al conducted the studies to determine the color changes of the ceramic brackets immersed in food solutions for only a short period of one month [26, 7, 2]. The duration of orthodontic treatment timing is about 15 months. The duration of this study is about 15 months, and is not carried out in any of the previous studies.

Investigating the color changes can be determined by anyone of these methods; spectrophotometer, colorimeters, digital photographic analysis and visual assessment.

Spectrophotometer analysis is an effective method for evaluating the color changes and used in several studies done by Lee et al, Olivera et al, Faltermeier et al and Yadav et al. A double beam spectrophotometer is used in this study, wherein a beam of light is allowed to pass through the object and the color of the object is assessed in terms of light transmittance [26, 7, 2]. Here color changes of the ceramic brackets of two different crystalline structures are determined.

When there is a higher demand for esthetics and the patient prefers the ceramic brackets, they expect the brackets to appear esthetically on direct vision throughout the procedure .A study conducted by Olivera et al used the visual assessment scale to determine the color changes of ceramic brackets on direct vision suggested by Mancuso et al varying from +5 to -5 [7, 8].

The purpose of the study is to evaluate the color stability of the monocrystalline and polycrystalline immersed in artificial saliva and nutritive health drink powder solution for duration of 15 months by UV spectrophotometer and visual assessment scale.

AIM AND OBJECTIVE OF THE STUDY

AIM :

1. To assess the color stability of ceramic brackets both monocrystalline and polycrystalline immersed in artificial saliva solution.

2. To assess the color stability of ceramic brackets both monocrystalline and polycrystalline immersed in artificial saliva solution and health drink powder solution intermittently.

OBJECTIVE:

To determine the esthetic superiority of monocrystalline and polycrystalline ceramic brackets.

REVIEW OF LITERATURE

The review of literature for the present study is given under the following headings:

A. **Ceramic brackets.**

B. **Artificial saliva**

C. **Nature of color**

D. **Various methods to assess color changes.**

A. REVIEW OF LITERATURE FOR THE CERAMIC BRACKETS:

The ceramic brackets have been described and reviewed in detail by various authors which are as follows:

1. Evolution of the ceramic brackets.
2. Manufacturing of ceramic brackets.
3. The optical property of ceramic brackets.
4. Color stability of the ceramic brackets.

1. EVOLUTION OF THE CERAMIC BRACKETS:

J S Russell(2005) [28], had described the evolution of ceramic brackets and various other esthetic brackets that were available before the introduction of ceramic brackets. The increase in the growing awareness about the superior esthetics among the people has led to the development of esthetic brackets. Earlier in 1970, the esthetic brackets were made of acrylic and polycarbonate material which had several disadvantages like poor strength, poor long term esthetic stability and brittle in nature. This was replaced by polycarbonate brackets reinforced with ceramic and metal slots which were significantly better than the previous brackets. But still there existed certain problems with these brackets such as loss of torque. In 1980, ceramic brackets were developed with superior esthetics among all other esthetic brackets. The ceramic bracket fabricated by various manufacturers is available. But still, the technical performance is not as much in the stainless steel metal brackets. Further development of ceramic brackets is required which performs equal to the metal brackets.

Patel et al(2014) [24]**,** had described the term 'esthetics' and its growing awareness among the population which has led to the development of tooth-colored brackets. Most of the patients seek orthodontic treatment for the correction of the malocclusion and appear to be esthetically acceptable after the treatment. Because of the growing awareness, there is a higher demand for esthetics and people started refusing visible orthodontic therapy. As a result, tooth-colored brackets made of acrylic and polycarbonate was developed. These brackets had many drawbacks such as poor strength, poor color stability, and deformation.

This was replaced by the polycarbonate brackets reinforced with ceramic and metal slots which were significantly better than the previous brackets. But a few problems still existed which led to the evolution of ceramic brackets. The ceramic brackets had the advantage of superior esthetics and better clinical performance. Two forms of ceramic brackets were available - monocrystalline and polycrystalline.

2. MANUFACTURING OF CERAMIC BRACKETS:

Swartz(1988) [22]**,** had described the manufacturing process of two types of ceramic brackets.

The single crystal brackets are produced by melting the aluminum oxide particles at the temperature of 2100 degrees Celsius and cooled slowly to become a crystal which is then milled into the shapes of the bracket. The polycrystalline ceramic brackets are fabricated by mixing the aluminum oxide particles with a binder and molded. The brackets are made from the molded shapes and the slots are made by diamond cutting tools. The advantage of the monocrystalline ceramic brackets appears to be more clear because of the greater grain size and fewer impurities present during the manufacturing process when compared to the polycrystalline ceramic brackets.

David Birnie(1990) [9]**,** had described the manufacturing of ceramic brackets and its clinical application in his literature. The material used for making the ceramic brackets is alumina. Monocrystalline ceramic brackets are made from synthetic sapphire whereas polycrystalline ceramic brackets are obtained by sintering the alumina with resin and machined. Alumina was used for making the ceramic brackets because it appears aesthetically good but its disadvantage is very expensive and brittle. The ceramic brackets made by different manufacturers available in the American orthodontics, Dentaurum, GAC, Lancer, ORMCO, Rocky mountains, 3M/ Unitek, Damon.

Karamouzos et al(1997) [3]**,** had described in his literature about the manufacturing and the clinical properties of the ceramic brackets. At present, all the ceramic brackets were composed of aluminum oxide. Based on the manufacturing process, it is divided into two forms i.e. monocrystalline and polycrystalline ceramic brackets. The major difference between the two forms of ceramic brackets is their optical properties. Polycrystalline brackets appear to be more translucent whereas monocrystalline brackets appear clearer and allow more light to pass through it. The study concluded that the ceramic brackets have become more popular among adult patients because of the growing awareness about the esthetics.

Yoshimura et al(2009) [39]**,** had described the light transmittance in the polycrystalline ceramic brackets. During the manufacturing process of polycrystalline ceramic brackets, a small amount of MgO particles are added to the aluminum oxide particles which has been sintered in a vacuum atmosphere to reduce the sintering pores. Even after the sintering process, the presence of residual pores affects the light transmittance through the polycrystalline alumina. Depending on the size of the pores, the incident light gets scattered. Larger the size of the pore, greater the amount of light gets scattered causing some degree of opacity. This is the reason for the limited light transmittance through the polycrystalline ceramic brackets.

3. OPTICAL PROPERTY OF CERAMIC BRACKETS:

Elliades et al(1995) [34]**,** conducted a study to examine the percentage of light transmitted through the ceramic brackets and also examine the effect of morphological and composition of brackets on the light transmittance. A total of 8 different brands of brackets were included in the study. Among the 8 brands, 6 brackets from each brand were evaluated. The percentage of light transmitted was analyzed by a double beam spectrophotometer of 320 to 700nm wavelength. This was followed by an electron probe analyzer, a device to produce images of the scanned electron microscope used to find the morphological and structural characteristics of the ceramic brackets. The results of the study showed that the morphology and composition of the brackets affect the amount of light passing through the ceramic brackets. The monocrystalline ceramic brackets allow more light to pass through it whereas the polycrystalline ceramic brackets allow only some amount of light to get transmitted and most of the light get scattered.

Samir E Bishara(1997) [29]**,** had described the manufacturing process and its influence on the optical properties of ceramic brackets. The optical property depends on the grain size of the ceramic material. An increase in the grain size increases the clarity of the ceramic but if the size becomes more than 30 micrometers, then the material becomes more brittle. The presence of the impurities which is added during the manufacturing process of polycrystalline ceramic brackets tends to reflect light which results in the opacity of the material. The monocrystalline ceramic brackets appear clearer than the polycrystalline ceramic brackets because of the presence of fewer impurities. The disadvantage of the monocrystalline and polycrystalline ceramic brackets is that they tend to discolor when exposed to oral condition by various food dyes.

Gautam et al(2007) [25]**,** had described the manufacturing process and the properties of ceramic materials in his literature. In 1986, ceramic brackets were introduced in the field of orthodontics. The ceramic brackets were available in two forms such as monocrystalline and polycrystalline. Other than these brackets, Zirconia brackets were also available had the disadvantage of opacity and its use was declined. The basic composition of the ceramic material is the alumina. The superior aesthetics of the ceramic materials is because of the alumina which provides a clear appearance. Among the two forms of ceramic brackets, monocrystalline ceramic brackets appear to be clearer because of the reduced impurities and larger grain size. Still, improvement in the ceramic brackets is carried out as equal to that of metal brackets.

Lee et al (2008) [37]**,** did a study to investigate how much the color gets reflected and transmitted through the esthetic brackets of eight different manufacturers. Out of the eight brands, four were ceramic brackets and four were plastic brackets of 0.018 slot in Roth prescription. Five brackets from each brand were chosen randomly and the color changes were assessed from the labial surface of the brackets. The amount of color reflected and transmitted esthetic brackets were determined by the spectrophotometer. The results of the study revealed that the monocrystalline ceramic brackets of the Inspire Ice brand were found to be lightest and the polycrystalline ceramic brackets of the Luxi II brand was found to be most yellowish in reflected color. The plastic brackets of brand Esther II had the highest transmittance and Silkon plus showed lower transmittance. The study concluded that the color and translucency of esthetic brackets depends upon their optical properties and also the composition.

Lopes Filho et al (2012) [11]**,** did a study to find optical characteristics of ceramic and plastic brackets and to assess how far it affects the visual perception. Eighty maxillary central incisors brackets of 16 manufacturers of 0.22 slot in Roth prescription were selected for the study. Among the 16 manufacturers, 12 were ceramic brackets and 4 were plastic brackets. Forty the number of patients with no habits, no history of previous orthodontic therapy, no smoking habits, and no fillings were included in the study. The color shade of 80 maxillary right and left central incisors was measured by a portable spectrophotometer. Five non-translucent brackets selected from each brand were also assessed using the spectrophotometer. To find out the color differences between the teeth and translucent brackets, bovine teeth were measured followed by bonding of the 5 brackets from each brand to the same teeth and measured by spectrophotometer. The results revealed that the greatest amount of direct light transmittance was observed with the brackets of the Radiance and Illusion brand. The study concluded that the optical characteristics of esthetics brackets affect visual perception. The translucent and non-translucent brackets were less visually perceptible in natural light.

Jauhar P Mohamed et al (2016) [15]**,** investigated the amount of light transmittance and shear bond strength of the two types of ceramic brackets and sapphire brackets. A total of 78 ceramic brackets were taken, out of which 27 were monocrystalline, 27 were polycrystalline and 27 were sapphire brackets. The light transmittance through the brackets was assessed utilizing a spectrofluorometer to measure the intensity of light. The brackets were bonded to the extracted maxillary and mandibular premolar teeth by using Transbond XT and light-cured for 30 seconds. The shear bond strength of the brackets was assessed by using a universal testing machine. The results of the spectrofluorometer study revealed that sapphire brackets showed a greater amount of light transmittance and increase in shear bond strength, followed by monocrystalline and polycrystalline.

Santini et al(2016) [4]**,** investigated the light transmitted energy through three types of ceramic brackets and also the adhesive at different exposure time intervals. Among the 3 brands of ceramic brackets, one brand was monocrystalline and the other two brands were polycrystalline ceramic brackets. The irradiance and light energy transmitted from the tip of the light-curing unit through the ceramic brackets and the adhesive was measured using the resin calibrator at different duration for 5, 10 and 20 seconds. The results of the study showed that monocrystalline ceramic brackets showed the highest light transmission and hardness of the adhesive cured was greater at 5, 10, 20 seconds. The polycrystalline ceramic brackets of two brands required an increase in the exposure of light for the curing of adhesive.

4. COLOR STABILITY OF THE CERAMIC BRACKETS:

Faltermeier et al(2007) [2]**,** analyzed the color stability of plastic and composite brackets by immersing in the food solutions and subjecting them in ultraviolet light. 160 central incisor brackets were assessed, out of which 120 brackets were composite brackets of 3 different manufacturers and 40 plastic brackets. The experimental group consisted of eight brackets from each company were placed in 3 different solutions such as red wine, tea and coffee and also placed in the distilled water which was the control group. These sets of brackets were subjected to Sunset aging device followed by a Xenon lamp to mimic the light. Readings were taken by spectrophotometer for every 24 hours and 72hours. The study concluded that both the plastic and composite brackets showed poor color stability and were most stained by red wine.

Wriedt S et al(2007) [33]**,** investigated the staining effects of various foods on the different types of tooth-colored brackets. Six different types of tooth-colored brackets were selected such as polycrystalline ceramic, polycarbonate, polyoxymethylene, plastic reinforced with fillers. The staining solutions used in the study were orange juice, black tea, red wine, coffee, curry, and cress in which ten brackets of each type were immersed and the control group consisted of another ten brackets of each type were immersed in deionized water for ten days and maintained at a temperature of 37 degrees Celsius. Photo aging was done by exposing the ten brackets to the UV irradiation. The color readings were assessed using the Easy shade spectrophotometer device before and after cleaning in an ultrasound deionized water bath.
The results of the study showed that most of the brackets showed discoloration after 5 days of immersion in tea, coffee, and wine. Polyoxymethylene brackets showed discoloration immediately after immersing in curry. The study concluded that certain foods when consumed produce discoloration of the esthetic brackets.

Lee et al(2008) [37]**,** did another study to find out the color parameters and color changes in the reflectance and transmittance of the esthetic brackets which had been subjected to thermal cycling. The esthetic brackets used for investigation were of 4 plastic and 4 ceramic of 0.018 slot with Roth prescription of different manufacturers. These brackets were subjected to thermal cycling between 5 degrees Celsius to 55 degrees Celsius for 5000 cycles at 15 seconds. The changes in the color which has been reflected and transmitted from the labial side of the esthetic brackets were determined by spectrophotometer. The results of the study revealed that color stability changes with different brands. The composition of the ceramic (plastic or ceramic) and the crystalline structure (monocrystalline or polycrystalline) do not affect color stability.

Lee et al(2011) [36]**,** conducted a study to determine the color changes of ceramic and plastic brackets they were correlated with the color changes of shade guide tabs. The maxillary central incisor brackets of 0.018 of Roth prescription were selected for the study. Eight different brands were taken, out of which four were plastic brackets and four were ceramic brackets. The shade guide tab from A1 to A4 was used instead of the teeth and stainless steel 16x22 wire was placed in the slot. The readings from the labial side of the brackets were taken spectroradiometer before and after the placement of the bracket below the slot. The results of the study showed that the color changes of the brackets were influenced by the shade guide tabs. The value was less for the A1 tab and more for the A4 tab. It was concluded that not only the translucency of the esthetic brackets affects the color stability the shade of the underlying teeth is also responsible for the esthetic performance of the brackets.

Yadav et al(2013) [26]**,** conducted a study to analyze and compare the color stability of ceramic brackets of different manufacturers placed in different food solutions. Among the 120 ceramic brackets of maxillary central incisor, 40 ceramic brackets of 3 brands such as American orthodontics, Liberal traders and 3M/Unitek were taken for the study and divided into 3 groups. For the control T0 reading was before immersion by the spectrophotometer. Ten ceramic brackets from each group were immersed in drinking water, tea, coffee, coke for a period of 6 days. The color changes were evaluated for 1 day, 3 days and 6 days by the spectrophotometer. The study concluded that almost all brackets showed discoloration and further studies are to be carried out in an oral environment to assess color stability.

Filho et al(2013) [11]**,** conducted a study to evaluate the color changes of esthetic brackets before and after the aging process and staining. The ceramic brackets were chosen for the study comprised of 80 maxillary central incisors bracket of 0.022 slots of Roth prescription of

16 different manufacturers. Among the 16 manufacturers, 12 were ceramic brackets and 4 were plastic brackets. A total of 5 brackets from each brand were subjected to the aging process by using tungsten filament ultraviolet lamp for 14 hours which is equal to the aging occurring for 3 years of orthodontic treatment. This was followed by staining using coffee and tea for seven days at 37-degree temperature. The color stability was assessed using a portable spectrophotometer and NBS system after aging and staining. The results showed that there was no significant difference when compared between the plastic and ceramic brackets. In comparison among the different brands of the same material, a significant difference was found. The study concluded that color stability showed variations among the different brands and cannot be assessed using the type of material.

Oliveira et al(2014) [7]**,** conducted a study to find how far the color of the monocrystalline and polycrystalline ceramic brackets remain stable after placing in various food solutions. The maxillary right central incisor ceramic brackets of 4 different manufacturers were chosen for the study. Among the 4 manufacturers, two were monocrystalline and two were polycrystalline ceramic brackets. The ceramic brackets chosen were of Roth prescription and 0.22 slot. A total of seven brackets from different brands were placed in different food solutions such as coke, coffee, red wine, black tea, and artificial saliva. Variations in the color of the brackets were evaluated by spectrophotometer for every 24hours, 7 days, 14 days and 21 days. The study concluded that the ceramic bracket tends to stain when exposed to various drinks consumed commonly by the people in day to day life. Both the crystalline structures do not undergo a color change in the same way and also it varied from different manufacturers.

Ismael et al (2014) [21]**,** did a study to investigate the color changes of tooth-colored brackets by plaque disclosing solutions. Sixty brackets were selected for the study in which 30 were polycarbonate brackets and 30 were ceramic brackets. For the control group, six brackets from each type were placed in ethanol. For the experimental group, 12 brackets from each type were placed in two plaque disclosing solutions such as Replay and Replasul for one hour in 96 well plates. Before analyzing the reading the test samples are placed in ethanol for 24 hrs to remove the deposits on the brackets. The color changes of the bracket were assessed by the reflectance spectrophotometer. The results of the study showed that polycarbonate brackets showed more staining with both the disclosing solutions whereas the ceramic brackets showed staining with the Replasul disclosing solution.

Axante et al (2014) [1]**,** had described the discoloration of the ceramic brackets by various substances. The major disadvantage of ceramic brackets is that it tends to stain over a while. Factors responsible for the discoloration of ceramic brackets can be of intrinsic and extrinsic factors. Intrinsic coloration is caused by water absorption, matrix composition, the content and the size of the particles. The discoloration which is caused by food solutions produces the extrinsic color. A study was conducted in which 3 brands of polycrystalline ceramic brackets were chosen and immersed in coffee, tea, coke, and artificial saliva and the readings were assessed using a spectrophotometer. The study concluded that all brackets showed discoloration on exposure to various food pigments. A spectrophotometer is a standard device for assessing the variation in color.

Kannan et al (2014) [18]**,** conducted a study to determine the color changes of three different manufacturers of polycrystalline ceramic brackets on exposure to various food dyes. Among 120 upper right central incisor ceramic brackets, 40 brackets of 3 different manufacturers were taken for the study. Ten ceramic brackets from each manufacturer were immersed in various food drinks such as tea, coffee, coca cola, and distilled water was chosen as control. The study was done for a period of 6 days. The color changes were assessed by means of spectrophotometer and the readings were taken before the immersion and after 1, 3 and 6 days. The study concluded that all the brackets showed color changes caused by the tea and coffee. Minimal discoloration was seen with the ceramic brackets immersed in coca cola.

Guignone et al(2015) [5]**,** did a study to determine the color stability of different brands of ceramic brackets placed in staining solutions. A total number of 90 maxillary central incisor brackets of 5 commercial brands were taken and divided into 5 groups each consisting of 18 brackets. The brackets were placed in staining solutions such as coke, red wine, coffee and artificial saliva for 14 days. The color changes were evaluated by spectrophotometer and visual inspection before immersion, and at 24hours, 72hours, 7 days and 14 days. The study concluded that the duration of the brackets exposed to the solution affects the amount of staining and different pattern of staining observed with different solutions. The radiance brand of the ceramic bracket (monocrystalline) showed significant color changes among the other brackets.

Hussain et al(2017) [12]**,** did a study to analyze the color stability of different types of esthetic brackets and the influence of food substances. About 120 esthetic brackets of 4 different types of brackets such as plastic, monocrystalline, polycrystalline and zirconium were included in the study. The control group comprised of the distilled water and the experimental group comprised of chili and budu sauce in which 10 brackets of each type were immersed for 72 hours in both groups. The color changes were assessed by spectrophotometer for every 24 hours, 48 hours and 72 hours. The results of the study showed that monocrystalline and zirconium showed the least color change and plastic brackets showed more color change. Monocrystalline ceramic brackets were shown to have good esthetic stability among all the esthetic brackets.

Tangjit et al(2018) [23]**,** did a study to evaluate the color changes of the ceramic brackets placed in different food colorants. A total of 108 brackets of 0.22 slot of Roth prescription fabricated from 4 manufacturers (Inspire Ice, Radiance Plus, Clarity, and W&H) were chosen for the study. They were immersed in food colorants such as Tom-Yum-Goong, yellow curry, green curry, and coffee at 37 degree Celsius as experimental and distilled water as a control group. 27 brackets from each brand were taken and 13 brackets were immersed in the food colorants for three days. Another 13 brackets were immersed in the food colorants for 7 days. The color changes were assessed by spectrophotometer. The study concluded that all the ceramic brackets undergo a color change when exposed to food colorants and coffee. Both the crystalline structure does not follow the same type of color change and variations were seen in brackets from different brands.

Yang et al(2019) [20]**,** had described a recent advanced method of customizing the ceramic brackets according to the color and shade of the patient's teeth for the satisfaction of the patient. The intraoral scanner is used to create a 3D image of the patient's dentition and a virtual model is obtained. This model is subjected to 3D printing technology and the customized ceramic brackets are made by the ceramic ingots. For the study, the customized ceramic brackets are compared with the commercial available ceramic brackets such as Clarity Advanced; Crystalline VII; Inspire ICE; Damon Q. The surface structure of the brackets is analyzed utilizing Scanned electron microscopy and shear bond strength, frictional resistance was measured by the universal testing machine. The study concluded that customized ceramic brackets made of lithium disilicate materials presented with the color shade matching with that of the natural tooth. No significant the difference was found in shear bond strength and the frictional resistance when compared with other ceramic brackets.

B. <u>REVIEW OF LITERATURE FOR ARTIFICIAL SALIVA</u>:

Polonczyk et al(2017) [27]**,** had described in his literature about the uses of the artificial saliva which has been required for many in-vitro studies. For the studies regarding the examination of the dental materials, it required the need for a condition that simulates the oral environment. In 1931, W. Souder and W.T. Sweeney were the two persons who reported the use of artificial saliva for the first time. Based on the research data, many formulations are available for the making of artificial saliva depending on the experiment conducted. On comparing the different formulations of the artificial saliva the composition varies but major chemical components used were $NaHCO_3$, NaCl, KCl. The pH of the saliva also varies from different formulations and has a range of 5 - 7.3. Further research on artificial saliva is being carried out, in improving the functions similar to that of human saliva.

C. REVIEW OF LITERATURE ON THE NATURE OF COLOR AND ITS PERCEPTION:

Brewer et al (2004) [14]**,** had described about the nature of color of an object and its perception on the human eye. Natural sunlight is the white light which has a spectrum of seven colors (vibgyor), each color having a particular wavelength. When the white light passes through an object, some of the light gets absorbed selectively and some of the light gets transmitted, this is of particular wavelength. The particular wavelength of light enters the eye and the color of the object is thus perceived. In the human eye, the retinal rods and cones are the sensors responsible for the different color perception.

James C. Ragain(2015) [13]**,** had described about the perception of color by the human eye in his literature. Color of an object refers to the optical property of that object. For an object to be visible to human eye, it should reflect or transmit the light from the external source. Human eye consists of retinal rods and cones which has the photoreceptors for light. Cones are responsible for the color vision and divided into red, green, blue. The light is converted into nerve impulses and thus the color of the object is experienced.

Bhat et al(2019) [35]**,** had described about how the translucency and surface texture of the object affects the color of the object in his literature. When the translucency of the material increases, much of the light get scattered within the material and it affects the esthetic appearance of the object. Surface texture also affects the esthetic appearance of the object. In case of a smooth surface the direction of light reflected remains the same and the object look more polished.

D.REVIEW OF LITERATURE FOR VARIOUS METHODS TO ASSESS THE COLOR CHANGES:

1. **Visual assessment and Colorimetry**
2. **Spectrophotometer**
3. **Digital analysis**
4. **Recent advances in color measuring systems**

1. VISUAL ASSESSMENT AND COLORIMETRY:

Johnston (1989) [17]**,** had described a method for visual assessment based on 'an expanded visual rating scale for appearance match (EVRSAM)' and also describes clinical colorimetry. The color of an object depends on the amount of light absorbed and reflected from that object. The perception of the color of the material for every individual changes from one person to another person and is a subjective factor. The visual error does occur with the visual observation of two objects when placed under different illumination. Another method of assessing the color of an object is the clinical colorimetry. This colorimeter device produces an illumination at 45 degrees and 0 degrees and allowed the light to pass through the samples. By this method, the colorimetric readings are taken. The study concluded that colorimetric evaluation produced consistent results whereas the visual assessment by the human eye may not be reliable because of the variations in the individual perceptions.

Mancuso et al(2007) [8]**,** did a study to assess the compare the color stability of facial silicones by visual assessment scale. Visual evaluation is done based on the visual assessment scale. The readings of the scale ranged from +5 to -5. The following values were assessed as +1 – slightly clearer; +2 - fairly clear; +3 - clear; +4 - very clear; +5 - extremely clear, - 5 – extremely dark; - 4 -very dark; -3 - dark; - 2 - fairly dark; - 1 - slightly darker; 0 - no change. This method of visual observation by two operators has been carried out in the present study.

2. SPECTROPHOTOMETER:

Lee et al(2016) [38]**,** conducted a study to investigate the color changes and the transmittance using the spectrophotometer and compare it with a shade guide. Brackets of five different compositions were included in the study. Among the five types, three were plastic and two were ceramic brackets of 0.018 slot with Roth prescription. To simulate the oral condition, 16X22 stainless steel wire was placed in the slot. The readings were taken by spectrophotometer and also by using the shade guide tabs under the white and black background. The study concluded that not only the color and transmittance required for selecting the ceramic brackets but also the color of the brackets should match the patient's teeth. The differences in color and transmittance are significantly affected by its composition and variations in brands.

Gupta et al(2005) [10]**,** conducted a study to determine the spectrophotometric assessment of color changes for tooth-colored material such as ceramic and composite when exposed to food solutions. These materials are exposed to beverages such as tea, coffee, coke, distilled water. The spectrophotometer is a standardized device used to measure the color changes easily and is expressed in numerical value by perceiving the color of the object. The study concluded that tooth-colored materials are affected by food solutions. Further in vivo studies are required to assess the color stability of the materials.

3. DIGITAL ANALYSIS:

Akyalcin et al(2012) [30]**,** conducted a study to determine the staining property of esthetic brackets by means of digital analysis. Ten different brands were taken for the study, out of which 5 were ceramic brackets and 5 were plastic brackets which comprised of 500 brackets in total. The brackets were exposed to the staining solutions at 2 levels i.e., light and heavy exposure for 6 months. The ten brackets from each brand were placed in each of the staining solutions. The staining solutions were black coffee, black tea, curry paste, red wine as experimental group and artificial saliva as control group placed in a hot water bath at temperature of 37-degree celsius. The digital images of the brackets were taken and analyzed using graphic software. The study concluded that the optical property of the ceramic brackets and plastic brackets change when exposing to the different drinks consumed. The time of exposure with the staining solution also increases the amount of discoloration.

Cal et al (2006) [6]**,** did a comparative study between the spectrophotometer analysis and digital analysis to determine its accuracy in color measurement. Three shade guides were measured using spectrophotometer and images were taken by digital camera along with the software which is computerized. The results of the study showed that the readings obtained from the spectrophotometer were similar to the measurements from the digital analysis. Both the methods are reliable for the measurement of color.

Jee-Ha Choi et al (2010) [16]**,** did a comparative study between the visual assessment and spectrophotometer analysis in measuring the color shade. Shade selection for fifty maxillary central incisors by visual analysis and spectrophotometer were done. On comparison between the two methods, the results of the study revealed that the measurements made by spectrophotometer were accurate than the visual assessment.

Stephen J. chu et al (2010) [32]**,** had described about the spectrophotometer, colorimeter and digital analysis and its uses in dentistry. Spectrophotometer was considered to be more accurate among all the color measuring devices. Colorimeters are less accurate than the spectrophotometer as it does not measure the light reflectance. A digital imaging system has been developed along with various softwares and is associated with the other color measuring devices which are much easier and less time consuming.

4. RECENT ADVANCES IN COLOR MEASURING SYSTEMS:

Smitha (2017) [31]**,** had described about various color measuring devices from the past to the present in his literature. Earlier different shade guides systems were used to match the color of the tooth shade. In early 1980, the filter colorimeter was introduced as a color measuring device for the dental use and its success was limited because of its inaccuracy and complex design. Another device called as spectrophotometer which is used to measure the amount of light reflected by an object at each wavelength. When the light from the spectrophotometer is allowed to pass through an object, some amount of wavelength is absorbed and some get transmitted. The color of the object is determined by the light transmittance of particular wavelength. The device measures the light transmittance and amplifies as electrical signals which are displayed as numerical values on the screen. This gives accurate measurement of the color. Digital camera technology have been developed which captures the digital image. Many millions of micro sensors are present to record the color of the images. Spectroradiometer is another device which works similar to the spectrophotometer used to measure the color.

The currently available systems are:

a. Shofu’s Shade - Chroma Meter

b. The Vita Easyshade - hand-held spectrophotometer

c. The ShadeScan - digital analysis

d. ShadeRite Dental Vision System - digital color analysis with colorimetric analysis

e. The SpectroShade - digital color imaging with spectrophotometric analysis

f. ClearMatch System - software used in digital analysis

MATERIALS AND METHODS

SAMPLING:

Forty ceramic brackets manufactured by American orthodontics were chosen for the study. Out of which, twenty were monocrystalline ceramic brackets (Radiance brand) and other twenty were polycrystalline ceramic brackets (20/40 brand).

GROUPING OF SAMPLES:

The ceramic brackets were divided into two groups:

1. Group A consists of 10 monocrystalline and 10 polycrystalline ceramic brackets.
2. Group B consists of 10 monocrystalline and 10 polycrystalline ceramic brackets.

Group A was sub grouped as M1 and P1 each comprising of 10 monocrystalline (AM1) and 10 polycrystalline (AP1) ceramic brackets.

Group B was sub grouped as M2 and P2 each comprising of 10 monocrystalline (BM2) and 10 polycrystalline (BP2) ceramic brackets.

PROCEDURE FOR THE STUDY:

Four petriplates (Borosil) containing the artificial saliva (made by B.N.Laboratory, Mangalore) was taken for the study. Among the four petriplates, two were placed under group A (control group) and two petriplates were placed under group B (experiment group).

The composition of artificial saliva was:

1. Na_2HPO_4 - 0.26gs/litre
2. NaCl - 6.7gs/litre
3. NaH_2PO_4 - 0.20gs/litre
4. KCl - 1.20gs/litre
5. $NaHCO_3$ - 1.50gs/litre
6. Bovine albumin - 0.1gs/litre

In the group A, the ceramic brackets comprising of subgroups M1 and P1 were immersed separately in 2 petriplates with artificial saliva continuously for a period of 15 months.

In the group B, the ceramic brackets comprising of subgroups M2 and P2 were immersed separately in 2 petriplates with artificial saliva solution and intermittently placed in health drink powder solution (1/2 teaspoon of boost/50 ml of water) for 10 minutes every day and returned back to artificial saliva for a period of 15 months.

The entire setup was placed inside the refrigerator (whirlpool) maintaining 4-8 degree Celsius regulated by a thermometer (Legacy pro 6).Once in a month, the saliva was changed and the pH of the saliva was maintained and checked using a litmus paper.

EVALUATION OF CERAMIC BRACKETS :

A total of 10 brackets were available in each of the four subgroups (AM1, AP1, BM2, and BP2). Two brackets (S1 and S2) of monocrystalline and polycrystalline were chosen randomly from group A and group B for the evaluation of color change by using spectrophotometer and visual assessment scale.

1. SPECTROPHOTOMETER ASSESSMENT:

The ceramic brackets were evaluated periodically at 0, 3, 6, 9, 12, 15 months using Spectrophotometer (UV−Vis−NIR Spectrometer Perkin Elmer Lambda 19) to assess the color change in the ceramic brackets periodically and the values were given as To (before immersion), T1 (3 months), T2 (6months), T3 (9months), T4 (12months), T5 (15 months).

A double beam Spectrophotometer device consists of light source (Deuterium UV, Tungsten−Halogen Vis/NIR) of wavelength 200 to 2500nm for reflectance which was passed through a collimater. This collimated beam enters the diffraction grating (i.e, prism) and converted into a spectrum of different wavelength. A slit was present which allowed a beam of particular wavelength to pass through the same. The amount of light transmitted through the sample was obtained. The digital reading was recorded as T0, T1, T2, T3, T4, and T5.

The initial value T0 was recorded by spectrophotometer before immersion and followed by visual assessment, the brackets was immersed in the artificial saliva solution.

The sequence was repeated for every 3 months and the spectrophotometer values for the brackets in group A and group B were recorded as T1, T2, T3, T4, T5 after immersion. The values obtained from spectrophotometer were tabulated in Armstrong (Å) units in Table 1 and Table 2.

2. VISUAL ASSESSMENT:

Before immersion in the artificial saliva, visual assessment for the same brackets (S1, S2) of group A and group B was done by 2 operators using the Visual assessment scale as suggested by Mancuso et al [8].

Mancuso et al [8] standardized the visual assessment scale with values vary from 5 to +5.

-5 (extremely dark)	+5 (extremely clear)
-4 (very dark)	+4 (very clear)
-3 (dark)	+3 (clear)
-2 (fairly dark)	+2 (fairly clear)
-1 (slightly darken)	+1 (slightly clear)

The initial value V0 was recorded according to the visual assessment scale before immersion and returned back to the artificial saliva.

The sequence was repeated for every 3 months and the visual assessment values of the ceramic brackets in the group A and group B were recorded as V1, V2, V3, V4, V5 after immersion. Inter operator variability was also assessed.

The visual assessment values given by operator 1 were tabulated as Table 3, 4 and operator 2 was tabulated as Table 5, 6.

LIST OF FIGURES

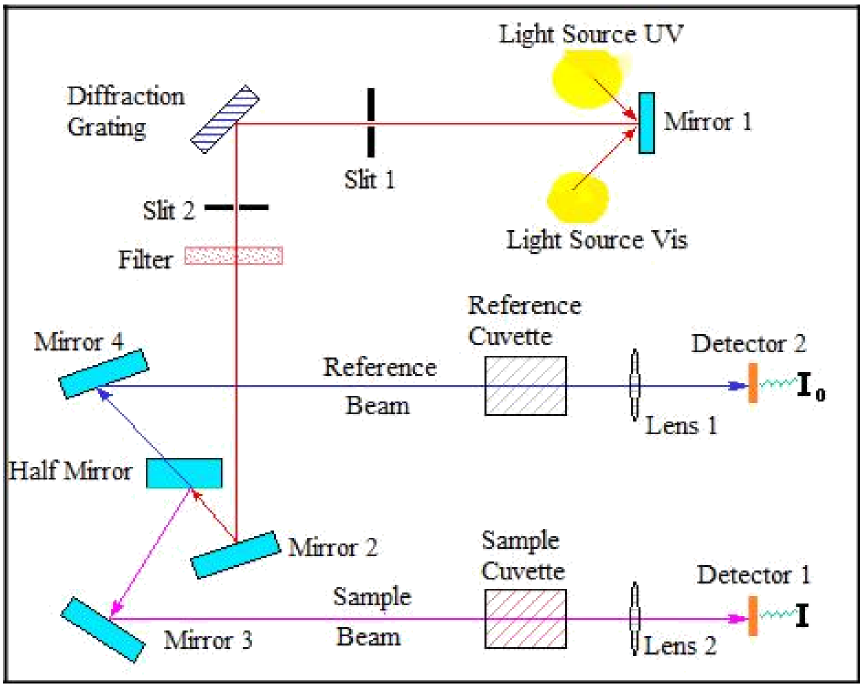
FIGURE-1

UV−Vis−NIR SPECTROPHOTOMETER

Specifications:

Model	:	UV−Vis−NIR Spectrometer Perkin Elmer Lambda 19
Lamp	:	Deuterium (UV), Tungsten−Halogen (Vis/NIR)
Detectors	:	Photomultiplier tube for UV−Vis, Lead−Sulphide cell (PbS) for NIR
Wavelength Range	:	185−3200 nm for Absorbance/transmission and 200−2500 Reflectance
Scan Speed	:	0.3 to 1200 nm/min
Wavelength accuracy	:	± 0.15 nm for UV/Vis & ± 0.6 nm for NIR
Base line flatness	:	± 0.001Å, 4 nm slit
Ordinate mode	:	Scan, time drive, wavelength programming, concentration
Photometric accuracy	:	± 0.003 Å or ± 0.08% T

FIGURE-2



SCHEMATIC DIAGRAM OF UV−Vis−NIR SPECTROPHOTOMETER

FIGURE – 3

MONOCRYSTALLINE CERAMIC BRACKETS

FIGURE – 4

POLYCRYSTALLINE CERAMIC BRACKETS

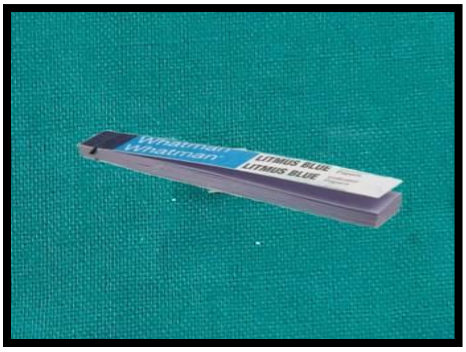
FIGURE – 5

ARTIFICIAL SALIVA

FIGURE – 6

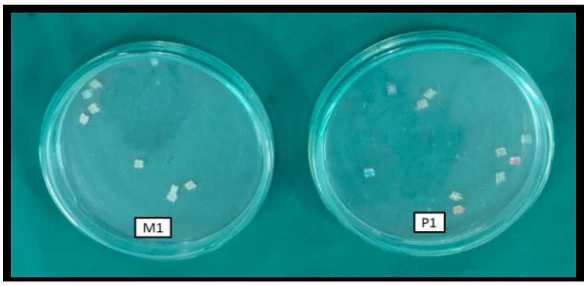
THERMOMETER

FIGURE – 7

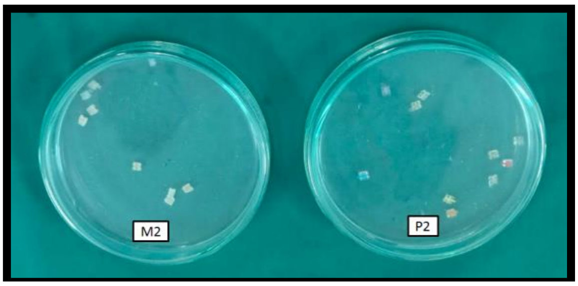


LITMUS PAPER

FIGURE-8 SAMPLES PLACED IN THE SOLUTION

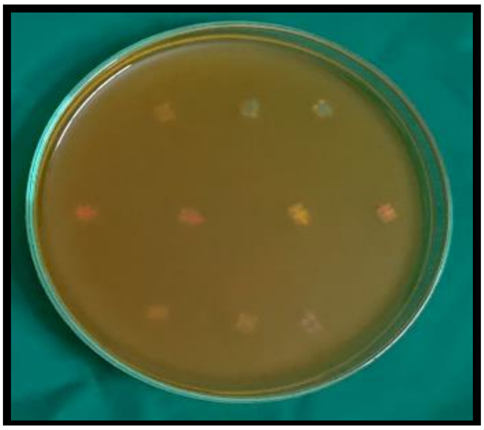


ARTIFICIAL SALIVA



ARTIFICIAL SALIVA AND HEALTH DRINK POWDER SOLUTION

FIGURE-9



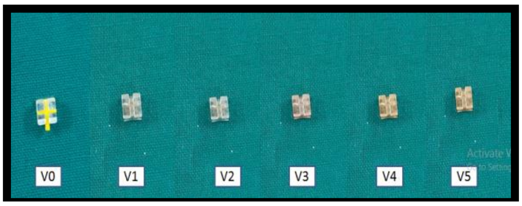
SAMPLES IN STAINING SOLUTION (BOOST)

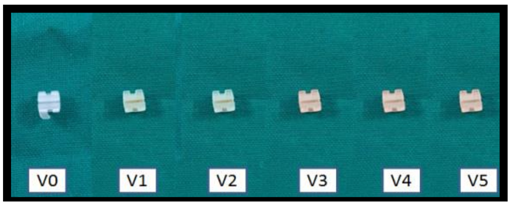
FIGURE-10

SAMPLES IN REFRIGERATOR

FIGURE – 11: CERAMIC BRACKETS BEFORE AND AFTER IMMERSION

ARTIFICIAL SALIVA

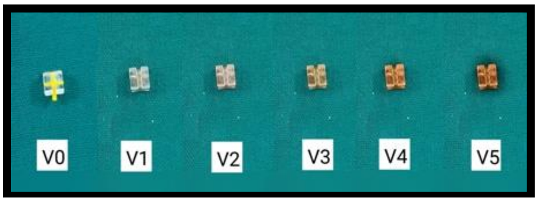


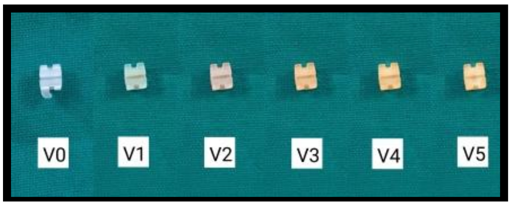


POLYCRYSTALLINE BRACKETS MONOCRYSTALLINE BRACKETS

ARTIFICIAL SALIVA AND HEALTH DRINK

POWDER SOLUTION





POLYCRYSTALLINE BRACKETS MONOCRYSTALLINE BRACKETS

TABLE-1: SPECTROPHOTOMETER EVALUATION –ARTIFICIAL SALIVA

Duration			0 Month	3 Month	6 Month	9 Month	12 Month	15 Month
Readings			T0	T1	T2	T3	T4	T5
Group A	M1	S1	5.79±0.23	5.49±0.20	5.14±0.27	4.94±0.25	4.76±0.23	4.54±0.20
		S2	5.75±0.75	5.44±0.16	5.17±0.88	4.96±0.79	4.74±0.32	4.52±0.32
Group A	P1	S1	5.48±0.27	5.21±0.23	4.97±0.21	4.80±0.27	4.69±0.30	4.36±0.31
		S2	5.45±0.65	5.28±0.49	5.09±0.39	4.84±0.98	4.65±0.88	4.25±0.78

Note:The values were given in Armstrong unit(Å).

TABLE-2: SPECTROPHOTOMETER EVALUATION - ARTIFICIAL SALIVA AND HEALTH DRINK POWDER SOLUTION

Duration			0 Month	3 Month	6 Month	9 Month	12 Month	15 Month
Readings			T0	T1	T2	T3	T4	T5
Group B	M2	S1	5.77 ±0.23	5.10 ±0.39	4.98 ±0.12	4.58 ±0.40	4.03 ±0.65	3.98±0.20
		S2	5.79±0.35	5.17±0.62	4.85±0.79	4.50±0.87	4.00±0.87	3.94±0.32
Group B	P2	S1	5.42 ±0.38	4.89 ±0.98	4.30 ±0.43	3.80 ±0.25	3.42 ±0.54	3.09 ±0.32
		S2	5.49±0.69	4.80±0.47	4.27±0.13	3.88±0.57	3.52±0.33	3.00±0.10

Note:The values were given in Armstrong unit(Å).

TABLE-3: VISUAL EVALUATION- ARTIFICIAL SALIVA (OPERATOR 1)

Duration			0 Month	3 Month	6 Month	9 Month	12 Month	15 Month
Readings			V0	V1	V2	V3	V4	V5
Group A	M1	S1	+4	+4	+3	+2	+1	+1
		S2	+4	+3	+2	+2	+1	+1
Group A	P1	S1	+4	+3	+2	+1	+1	-1
		S2	+4	+3	+2	+1	-1	-1

TABLE-4: VISUAL EVALUATION - ARTIFICIAL SALIVA AND HEALTH DRINK POWDER SOLUTION

Duration			0 Month	3 Month	6 Month	9 Month	12 Month	15 Month
Readings			V0	V1	V2	V3	V4	V5
Group B	M2	S1	+4	+2	+2	-1	-3	-3
		S2	+4	+3	+2	-1	-3	-3
Group B	P2	S1	+3	+1	-2	-2	-3	-4
		S2	+3	-1	-1	-2	-3	-4

TABLE-5: VISUAL EVALUATION - ARTIFICIAL SALIVA (OPERATOR 2)

Duration		0 Month		3 Month	6 Month	9 Month	12 Month	15 Month
Readings		V0		V1	V2	V3	V4	V5
Group A	M1	S1	+5	+3	+3	+1	+1	-1
		S2	+4	+3	+2	+2	+1	-1
Group A	P1	S1	+5	+3	+3	+1	-1	-2
		S2	+4	+3	+2	+1	-1	-2

TABLE-6: VISUAL EVALUATION - ARTIFICIAL SALIVA AND HEALTH DRINK POWDER SOLUTION

Duration		0 Month		3 Month	6 Month	9 Month	12 Month	15 Month
Readings		V0		V1	V2	V3	V4	V5
Group B	M2	S1	+5	+2	+1	-1	-3	-3
		S2	+4	+3	+2	-1	-3	-3
Group B	P2	S1	+5	+2	-1	-2	-2	-4
		S	+5	+2	+1	-1	-2	-4

STATISTICAL ANALYSIS

Statistical analyses were performed with IBM SPSS version 17(SPSS Inc., Chicago, IL). Descriptive statistics was computed. The data was found to be in normal distribution using Shapiro wilks test.

One way Analysis of Variance (ANOVA) was carried out to analyze significant differences in color changes in terms of mean light transmission between the four subgroups at different time intervals. These analyses were preceded by a test of homogeneity of variances. Hence homogeneity of variances was violated; ANOVA was replaced by Brown-Forshyte test.

The formula used for the ANOVA analysis was

$$\textbf{ANOVA} = \frac{\mathbf{BMS - WMS}}{\mathbf{BMS + (n-1)WMS}}$$

Where

BMS= comparison between the mean sum of squares of the subgroups

WMS = comparison within the mean sum of squares of the subgroups

n = number of observations

The formula for **mean:**

$$\bar{x} = \frac{\sum x}{N}$$

Where $\sum$ **X** is the sum of the value of each observation in a group and **N** is the number of observations obtained.

The formula for **standard deviation**:

$$S = \sqrt{\frac{\sum(X - \bar{X})^2}{N}}$$

Where $\sum$ is the sum, **X** is the value of each observation in a group, $\bar{X}$ is the arithmetic mean and N is the number of observations obtained.

Post hoc Tamhane’s test is used to determine the significant between the four subgroups by multiple comparisons in pair.

Repeated measures Multivariate Analysis of variance (RMANOVA), carried out by the Pillai Trace test, and were used to evaluate the influence of one or more variables on the degree of staining. Pillai trace test is used as test statistic in RMANOVA which is a positive valued statistic ranging from 0 to 1. Significance was set as $p < 0.05$.

RESULTS

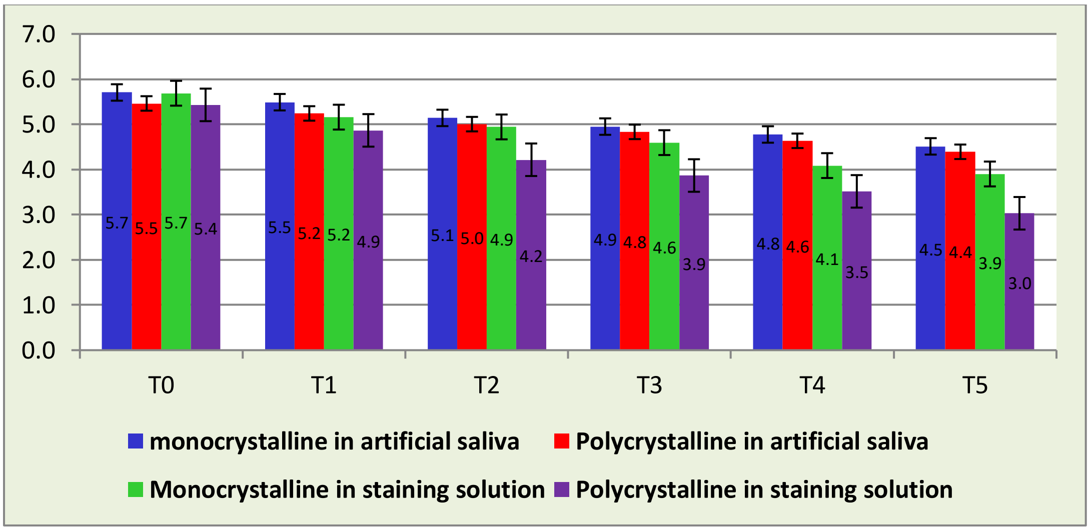
SPECTROPHOTOMETER ASSESSMENT:

TABLE.7: Comparison of mean light transmission between 4 subgroups at different time intervals

	Artificial saliva		Staining solution		
	Monocrystalline	**Poly crystalline**	**Monocrystalline**	**Poly crystalline**	**P value**
T0[a]	5.70 ± 0.06	5.46 ± 0.04	5.68 ± 0.03	5.42 ± 0.04	0.076
T1	5.48 ± 0.06	5.24 ± 0.07	5.15 ± 0.05	4.86 ± 0.06	0.001*
T2	5.14 ± 0.06	5.00 ± 0.06	4.94 ± 0.03	4.21 ± 0.05	0.001*
T3 [a]	4.94 ± 0.03	4.83 ± 0.11	4.59 ± 0.05	3.86 ± 0.04	0.001*
T4 [a]	4.77 ± 0.05	4.63 ± 0.10	4.08 ± 0.05	3.51 ± 0.04	0.001*
T5 [a]	4.51 ± 0.04	4.39 ± 0.11	3.9 ± 0.03	3.03 ± 0.06	0.001*

One way ANOVA test; * shows ($p<0.05$). Notes: 1) In times marked with [a], variance are not equal. In this case, ANOVA was replaced by Brown-Forsythe test.

GRAPH 1: Comparison of mean light transmission between 4 subgroups at different time intervals



GRAPH 2: Comparision of mean light transmission based on time trend between monocrystalline and polycrystalline brackets

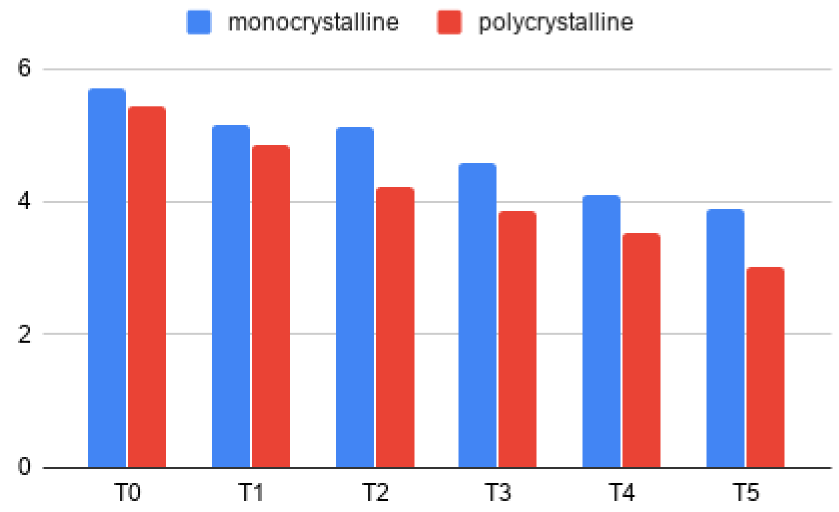


TABLE.8: Post hoc pairwise multiple comparison of mean light transmission between groups

Time	(I) grp	(J) grp	Mean difference (I-J)	Std error	p value
T0	monocrystalline in artificial saliva	Polycrystalline in artificial saliva	.24300*	0.02	0.001*
		Monocrystalline in staining solution	0.02	0.02	0.876
		Polycrystalline in staining solution	.27500*	0.02	0.001*
	Polycrystalline in artificial saliva	Monocrystalline in staining solution	-.22600*	0.02	0.001*
		Polycrystalline in staining solution	0.03	0.02	0.50
	Monocrystalline in staining solution	Polycrystalline in staining solution	.25800*	0.02	0.001*
T1	monocrystalline in artificial saliva	Polycrystalline in artificial saliva	.24900*	0.03	0.001*
		Monocrystalline in staining solution	.33100*	0.03	0.001*
		Polycrystalline in staining solution	.62400*	0.03	0.001*
	Polycrystalline in artificial saliva	Monocrystalline in staining solution	.08200*	0.03	0.029*
		Polycrystalline in staining solution	.37500*	0.03	0.001*
	Monocrystalline in staining solution	Polycrystalline in staining solution	.29300*	0.03	0.001*
T2	monocrystalline in artificial saliva	Polycrystalline in artificial saliva	.13800*	0.03	0.001*
		Monocrystalline in staining	.20000*	0.03	0.001*

		solution			
		Polycrystalline in staining solution	.92600*	0.03	0.001*
	Polycrystalline in artificial saliva	Monocrystalline in staining solution	0.06	0.03	0.081
		Polycrystalline in staining solution	.78800*	0.03	0.001*
	Monocrystalline in staining solution	Polycrystalline in staining solution	.72600*	0.03	0.001*
T3	Monocrystalline in artificial saliva	Polycrystalline in artificial saliva	.11700*	0.03	0.004*
		Monocrystalline in staining solution	.35500*	0.03	0.001*
		Polycrystalline in staining solution	1.08300*	0.03	0.001*
	Polycrystalline in artificial saliva	Monocrystalline in staining solution	.23800*	0.03	0.001*
		Polycrystalline in staining solution	.96600*	0.03	0.001*
	Monocrystalline in staining solution	Polycrystalline in staining solution	.72800*	0.03	0.001*
T4	monocrystalline in artificial saliva	Polycrystalline in artificial saliva	.14000*	0.03	0.001*
		Monocrystalline in staining solution	.68800*	0.03	0.001*
		Polycrystalline in staining solution	1.25900*	0.03	0.001*
	Polycrystalline in artificial saliva	Monocrystalline in staining solution	.54800*	0.03	0.001*
		Polycrystalline in staining solution	1.11900*	0.03	0.001*
	Monocrystalline in staining solution	Polycrystalline in staining solution	.57100*	0.03	0.001*
T5	monocrystalline in artificial saliva	Polycrystalline in artificial saliva	.12000*	0.03	0.005*
		Monocrystalline in staining solution	.61100*	0.03	0.001*
		Polycrystalline in staining solution	1.48100*	0.03	0.001*
	Polycrystalline in artificial saliva	Monocrystalline in staining solution	.49100*	0.03	0.001*
		Polycrystalline in staining solution	1.36100*	0.03	0.001*
	Monocrystalline in staining solution	Polycrystalline in staining solution	.87000*	0.03	0.001*

Post hoc Tamhane' s test *. The mean difference is significant at the 0.05 level.

TABLE .9: Descriptive statistics for each factor in Multivariate analysis

Effect		Mean	Std. Error
Bracket	Monocrystalline	4.911	0.009
	Polycrystalline	4.54	0.009
Solution	Artificial saliva	5.011	0.009
	Staining solution	4.44	0.009
Time	T0	5.57	0.008
	T1	5.188	0.01
	T2	4.825	0.009
	T3	4.56	0.011
	T4	4.252	0.011
	T5	3.958	0.012

TABLE.10: Multivariate test for significance of color change for brackets exposed to different staining solutions: time and bracket type factors.

Intra individual factor = time.

Effect	Pillai's Trace	F			p value	Effect size (Partial Eta Squared)	Observed power
Time	0.998	3.5553	5	32	0.001*	0.998	1
Time * brackets	0.797	25.094	5	32	0.001*	0.797	1
Time * solution	0.981	3.2772	5	32	0.001*	0.981	1
Time* brackets * solution	0.901	58.509	5	32	0.001*	0.901	1

RMANOVA (Pillai trace method) ; * shows ($p<0.05$)

TABLE .11: Descriptive statistics for effect of combined factor (Time* brackets * solution) in Multivariate analysis

Type of brackets	solution	Time	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Monocrystalline	Artificial saliva	T0	5.70	0.02	5.67	5.74
		T1	5.49	0.02	5.45	5.53
		T2	5.14	0.02	5.11	5.18
		T3	4.95	0.02	4.90	5.00
		T4	4.77	0.02	4.73	4.82
		T5	4.51	0.02	4.46	4.56
	Staining solution	T0	5.69	0.02	5.66	5.72
		T1	5.16	0.02	5.12	5.20
		T2	4.94	0.02	4.91	4.98
		T3	4.59	0.02	4.55	4.64
		T4	4.09	0.02	4.04	4.13
		T5	3.90	0.02	3.85	3.95
Polycrystalline	Artificial saliva	T0	5.46	0.02	5.43	5.49
		T1	5.24	0.02	5.20	5.28
		T2	5.00	0.02	4.97	5.04
		T3	4.83	0.02	4.79	4.88
		T4	4.63	0.02	4.59	4.68
		T5	4.39	0.02	4.34	4.44
	Staining solution	T0	5.43	0.02	5.40	5.46
		T1	4.87	0.02	4.83	4.91
		T2	4.22	0.02	4.18	4.25
		T3	3.87	0.02	3.82	3.91
		T4	3.52	0.02	3.47	3.56
		T5	3.03	0.02	2.98	3.08

RESULTS

SPECTROPHOTOMETER ASSESSMENT:

The mean values obtained from the spectrophotometer were in terms of light transmittance. As the staining of the ceramic brackets increases, the light transmittance decreases. The mean values were evaluated by One way ANOVA and Brown Forsythe test; the results were tabulated in Table 7. This shows the comparison of mean light transmission between the four subgroups at different time intervals.

From the Table 7, it was found that the significant differences in the color changes were seen in all the time period (T1-T5) and it was statistically significant except for the baseline values (T0).

On comparing the mean values between the four subgroups, the mean value of the polycrystalline ceramic brackets was about 3.03 and the monocrystalline ceramic brackets was about 3.90 at the end of 15 months when placed in staining solution. The mean value of polycrystalline ceramic brackets was about 4.39 and the monocrystalline ceramic brackets were about 4.51 at the end of 15 months when placed in artificial saliva. This shows that the polycrystalline brackets produced greater staining and showed less light transmittance which was statistically significant (p =0.001) whereas monocrystalline brackets had less stain uptake and more light transmittance in all time intervals.

This Graph 1 represents the comparison of mean light transmission between groups at different intervals. There is overall decrease in the mean light transmission of the ceramic brackets over a period of time in all groups which means that there is gradual increase in the degree of stain uptake from T0 to T5. At T0, the mean values of monocrystalline ceramic brackets before immersion in both solutions showed similar values and the same with the polycrystalline ceramic brackets has been observed. At time of T1, T2, T3, T4 and T5, among the four subgroups the polycrystalline ceramic brackets immersed in staining solution showed the maximum stain uptake with decreased light transmittance. The monocrystalline in artificial saliva showed the less stain uptake with increased light transmittance.

From the Graph 1 and Graph 2, the monocrystalline ceramic brackets immersed in the staining solution do not show much of color change at T1, T2, and T3. The maximum color uptake was seen in T4 and T5 on exposure to staining solution. The polycrystalline ceramic brackets do not show much of color change at T1 whereas there was significant color change at the time T2, T3, T4 and T5 on exposure to staining solution.

On comparing both the Graphs, at the time of T2, T3, T4 and T5 the color uptake of the polycrystalline ceramic brackets was greater than the monocrystalline ceramic brackets immersed in staining solution. This shows the influence of time on the degree of staining in the brackets.

The Table8 showed the pairwise possible comparisons between groups to substantiate in which group such differences was resulted using the Post hoc Tamhane's test. It was found that there was no significant difference in color alteration in similar brackets before the immersion in different solution at baseline (T0) but significant color changes occurred after immersion of brackets in the staining solution.

The mean difference between the monocrystalline and polycrystalline ceramic brackets placed in staining solution was about 0.258 at T0 (before immersion).At the end of 15 months (T5), the polycrystalline ceramic brackets showed greater mean difference of 0.870 when compared with monocrystalline ceramic brackets which was statistically significant.

Comparatively polycrystalline brackets showed more color alteration from T1 to T5. The brackets immersed in the health drink staining solution also showed more color change from T1 to T5. This explains that the effect of crystalline structure of the ceramic brackets and type of staining solution on the degree of stain uptake.

Table 9 represents the descriptive statistics in which “a word” is given to represent to the summarized data. Three factors were considered as descriptive statistics:

1. Bracket
2. Solution
3. Time

The mean values were summarized under each factor and Repeated measures of Mutlivariate analysis (RMANOVA) was carried out.

The Table 10 represents the degree of color change and how the multivariate analysis is effective in explaining the variance of outcome variable. The results of RMANOVA and Pillai trace method which shows the effect of time, bracket and the staining solution on the color change.

Considering the time factor, the observed power value was 1 which means there is greater effect of time factor on the stain uptake which means that the stain uptake had increased between the time periods. On combining two factors the time and type of brackets, the power observed was 1 and shows polycrystalline brackets had more color alteration over a time period. Similarly for the other two factors time and type of staining solution, the power observed was 1 and shows greater effect on the color change shows that staining solution produced more color changes over a period of time. Similarly in combined Time* brackets * solution effect, polycrystalline brackets in staining solution showed significantly higher color uptake over a time period. All the three factors showed significant effect on the color change which was statistically significant.

The Table 11 describes the effect of 3 combined factors such as time*brackets*solution on the color change which is done by Multivariate analysis. This shows that on exposure to staining solution it led to higher staining patterns on both bracket types at all-time intervals and relatively polycrystalline brackets in staining solution showed higher degree of staining.

VISUAL ASSESSMENT:

The Table 3 and 4 under the visual assessment showed the observations of operator 1 for the monocrystalline and polycrystalline immersed in artificial saliva and staining solution. At the end of 15 months, operator 1 observed that the polycrystalline ceramic brackets appeared to be slight darker than the monocrystalline ceramic brackets when immersed in staining solution based on the visual assessment scale given by Mancuso et al.

The Table 5 and 6 under the visual assessment showed the observations of operator 2 for the monocrystalline and polycrystalline immersed in artificial saliva and staining solution. The operator 2 observed that the polycrystalline ceramic brackets appeared to be darker than the monocrystalline ceramic brackets placed in staining solution.

From the overall visual assessment readings, it showed that polycrystalline brackets showed more staining than the monocrystalline ceramic brackets on direct observation based on visual assessment scale. The inter operator variability was assessed to find out the variations in the readings of the observers and it was about 37%.

DISCUSSION

Many orthodontic patients are concerned about the unaesthetic appearance of the metal brackets and were in need of an alternative. To overcome this problem, the ceramic brackets were introduced in 1980 and are aesthetically accepted by the patients. Based on the manufacturing process, two forms of ceramic brackets are available [22, 9, 3] . They are monocrystalline and polycrystalline ceramic brackets which were described by Birnie [9], Russell [28], Bishara et al [29]. Even though the ceramic brackets satisfied the esthetic needs of the patient, there was a drawback that these ceramic brackets undergo staining over a period of time.

Axante et al [1] and Faltermier et al [2] reported that the external discoloration of the ceramic brackets is caused by food solutions and mouth rinses. The discoloration of the ceramic brackets can also occur due to internal factors such as composition, structure and water absorption. Faltermier et al and Arthur et al [2] found that the amount of color changes in the esthetic brackets can be influenced by a number of factors such as type of staining solution, structure and composition of the brackets, oral hygiene, water absorption. In the present study, three factors were considered such as duration of immersion, crystalline structure of the brackets and the type of staining solution.

The purpose of the present in vitro study was to investigate the color stability of monocrystalline and polycrystalline ceramic brackets immersed in artificial saliva and a potentially staining health drink solution intermittently.

For assessing the color stability of esthetic brackets many authors had used different solutions as medium for immersion. Filho et al [13] and Kannan et al [18] used common beverages like black tea, coffee and coke. Tangjit et al [23] used yellow curry and green curry; Wried et al[33] used orange juice, red wine and curry; Ismael et al [21] used different plaque solutions as the staining solution. In the present study, nutritive health drink powder solution has been used as the staining solution as majority of the adolescent patients consumes the health drink. Polonczyk et al [27] suggested the use of artificial saliva in the in vitro studies in order to simulate the oral environment and was chosen as a medium for immersion in the present study. However, the composition of artificial saliva varies among different manufacturers and does not function in the same way as the natural saliva does [27].

Olivera et al [7] immersed the brackets in the staining solutions for a period of 21days. Faltermier et al [2] investigated the color stability after the immersion for about 72 hours. Kannan et al [18] immersed the brackets for about 6 days. Wried et al [33] evaluated the color changes after 5 days of immersion period. The duration of immersion was found to be less in all the previous studies. Hence the duration of immersion in the present study was taken as 15 months which is the same duration as the orthodontic treatment.

Color changes can be assessed by different methods such as spectrophotometer, colorimeters, digital analysis and visual assessment. Yadav et al [26], Lee et al [37], and Olivera et al [7] used spectrophotometer for the measuring of color changes of the aesthetic brackets. Akyalcin et al [30] analysed the staining of the brackets using digital analysis. Johnston [17] by using the clinical colorimetry and visual assessment evaluated the color of the restorations. Mancuso et al used the visual assessment to determine the color stability of facial silicones [8].

Cal et al [6], Jee Ha Choi et al [16], and Stephen J. Chu et al [32] reported that the measurements made from the spectrophotometer and the digital analysis was similar and more accurate than the colorimeter and visual assessment method.

Gupta et al considered the spectrophotometer to be gold standard device for measuring the color changes [10]. Hence, spectrophotometric method of assessing the color changes has been chosen in the present study.

UV- Vis – NIR Spectrohotometer Perkin Elmer Lambda 19 model has been used for measuring the color changes in terms of light transmittance in the present study. When the light from the device is allowed to pass through the ceramic brackets some of the light get transmitted which is perceived as the color of the object as described by Smitha in her literature [31]. The spectrophotometric readings were expressed as numerical values.

In the present study, visual assessment scale given by Mancuso et al [8] was used to determine the color changes of the ceramic brackets on direct vision. However Johnston reported that the visual assessment method is not reliable and visual error do occur because of the variations in individual perceptions [17].

In the present study, the color changes in the ceramic brackets were assessed before immersion and after immersion for every 3 months by spectrophotometer and visual assessment scale given by Mancuso et al [8] for a period of 15 months.The visual assessment was done by two operators.

The readings obtained from the spectrophotometer and visual assessment were tabulated and the data analysis was done usingIBM SPSS version 17(SPSS Inc., Chicago, IL). One way Analysis of Variance (ANOVA) and Multivariate Analysis of variance were done to analyse the differences in color changes in terms of light transmission.Significance was set as $p < 0.05$.

In the spectrophotometer assessment, the results of the multivariate analysis showed that both types of ceramic brackets undergo staining gradually in all time periods except for the baseline value i.e., before immersion. The monocrystalline ceramic brackets showed maximum stain uptake during T4 and T5 whereas the polycrystalline ceramic brackets showed maximum stain uptake during T2, T3, T4 and T5 on exposure with the staining solution. There is a gradual increase in the degree of staining over a period of time for both monocrystalline and polycrystalline ceramic brackets immersed in staining solution

. Olivera et al [7] and Guignone et al [5] concluded that there was gradual increase in the stain uptake with increase in the time of immersion which is in accordance with the present study. This explains how the duration of immersion affects the degree of staining. Tangjit et al [23] reported that both the monocrystalline and polycrystalline ceramic brackets do not follow the same pattern of staining which is in contrast with the present study.

From the one way analysis of variance (ANOVA), the polycrystalline type of ceramic brackets placed in staining solution showed greater staining and the monocrystalline ceramic brackets placed in artificial saliva showed least staining at the end of 15 months.The results from the studies done by Olivera et al [7] and Hussain et al [12] showed that monocrystalline ceramic brackets produced least staining which is in accordance with the present study.

Guignone et al showed that monocrystalline ceramic brackets showed more staining which is in contrast with the present study [5]. Most of the previous studies showed the comparison between different brands of the ceramic brackets and very few studies had compared the two crystalline structures by using the spectrophotometer [7, 12]. Hussian et al and Ismael et al compared the brackets made of different materials such as plastic, composite, monocrystalline, polycrystalline, polycarbonate and zirconium [21, 12.] The results of the study showed that monocrystalline type of ceramic brackets showed least staining which explains that the material of the bracket do influence the stain uptake. This factor was not considered in the present study as the comparison was between two crystalline structures.

The effect of the crystalline structure over the staining of the brackets is explained by Yoshimura et al [39] , Jauhar P Mohamed et al [15] and Elliades et al [34] . Based on the manufacturing process the monocrystalline ceramic brackets appear more clear and called as translucent brackets which show more light transmittance whereas the polycrystalline ceramic brackets are non-translucent brackets and show limited light transmission [3] . When the ceramic brackets are exposed to staining solution, they undergo discoloration irrespective of the crystalline structure. As the stain uptake of the ceramic brackets increases, the translucency of the material reduces and thus light transmittance is limited [39, 31, 35]. This explains that how the crystalline structure do influence the degree of staining and the light transmittance.Lee et al in his study determined that both crystalline structure of ceramic brackets had stain uptake and there is no correlation between the crystalline structure and staining which is in contrast with the present study [37].

Another factor to be considered is the type of staining solution used for immersion of the ceramic brackets. In the present study, the nutritive health drink powder solution caused a greater degree of staining than the artificial saliva. Few other studies done by Wried et al [33] and Axante et al [1] used sauce, curry, red wine as the staining solution which produced greater degree of staining. This shows that not only the crystalline structure but also the type of staining solution affect the degree of stain uptake which is in accordance with the present study.

The results of the present study showed the combined effect of duration of immersion, type of brackets and the type of the staining solution do influence the degree of staining. There is a gradual increase in the degree of staining over a period of time for both monocrystalline and polycrystalline ceramic brackets immersed in staining solution. At the end of 15 months, monocrystalline ceramic brackets produced less staining and was better than the polycrystalline ceramic brackets by 25%.

From the visual assessment scale given by Mancuso et al, the polycrystalline ceramic brackets placed in staining solution appeared to be darker than the monocrystalline ceramic brackets reported by 2 operators. Interoperator variability is about 37%. Even though the visual assessment scale is not reliable method for evaluating the color change, it can be used along with a standard method like spectrophotometer.

The present study is of invitro study and further in vivo studies are needed to evaluate the color stability of ceramic brackets in the oral environment.

SUMMARY AND CONCLUSION

The results from the spectrophotometer shows that the polycrystalline ceramic brackets showed greater degree of stain uptake when immersed in nutritive health drink solution and the monocrystalline ceramic brackets showed least staining at the end of 15 months. There was significant difference in the color change between the monocrystalline and polycrystalline for all the time intervals except for the baseline reading (T0). There was a gradual increase in the stain uptake for both the brackets placed in staining solution.

The degree of staining for the monocrystalline was maximum at the time T4 and T5 and for the polycrystalline it was maximum at T2, T3, T4 and T5 from the Graph 2 and 3.

From the visual assessment scale given by Mancuso et al showed that polycrystalline ceramic brackets appeared darker than monocrystalline brackets on direct vision. However the visual assessment is not accurate method for color assessment, but can be used along with the standard method.

Three factors influenced the degree of staining from the present study:

1. Duration of immersion
2. Type of bracket
3. Type of staining solution

From the present study, it was concluded that both the monocrystalline and polycrystalline ceramic brackets undergo staining when placed in staining solution. Comparatively monocrystalline ceramic brackets produced less stain and were better than the polycrystalline ceramic brackets about 25%. The combined effect of time, type of bracket and type of staining solution had influenced the degree of stain uptake.

However the present study is in vitro study, further in vivo studies are to be carried out to find the color stability of the ceramic brackets.

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This certificate is awarded to Dr. R. SHANTHINI

for participating as Delegate / ~~Resource Person~~ in the Workshop on **"Research Methodology and Biostatistics: How To Do a Good Dissertation & Publish?"** organized by the Department of Epidemiology, The Tamil Nadu Dr.M.G.R. Medical University from 25.7.18 to 27.7.18.

The participation in this workshop as a delegate is rewarded with 30 credit hours.

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To

Dr.R.Shanthini,
Postgraduate Student,
Dept. of Orthodontics,
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*****

Your dissertational study titled "COLOR STABILITY OF CERAMIC BRACKETS IMMERSED IN ARTIFICIAL SALIVA AND A POTENTIALLY STAINING HEALTH DRINK SOLUTION – AN INVITRO STUDY" presented before the ethical committee on 14th Dec. 2017 has been discussed by the committee members and has been approved.

You are requested to adhere to the ICMR guidelines on Biomedical Research and follow good clinical practice. You are requested to inform the progress of work from time to time and submit a final report on the completion of study.

Signature of the Chairman
(Dr. Philip Robinson)

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19-08-2019

Certificate

This is certifying that the results of the study were obtained using spectrometer from the institution of under my guidance.

Place : Erode
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Yours faithfully,

(M. Parthibavarman)

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