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EFFECT OF VARIOUS FACTORS ON PROPERTIES OF MAXILLOFACIAL SILICONES- A REVIEW

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ABSTRACT

Purpose- The aim of this review was to understand the effect of disinfectants, aging, storage time, pigments and opacifiers on dimensional stability, detail reproduction, mechanical properties and colour stability of maxillofacial silicones.
Study selection- A computerized database search using PubMed was conducted for peer-reviewed scientific research studies regarding the effect of disinfectants, aging, storage period, pigments and opacifiers on various properties of maxillofacial silicones, with no restriction for publication years. The search engine provided numerous results, out of which 54 scientific research papers, case studies, literature reviews were considered relevant for this review.
Results- A total of 123 titles were identified with the initial search. 70 were selected based on title and abstract. Of these after discussion and complete reading, 54 were selected according to the inclusion and exclusion criteria, all of which were in vitro studies.
Conclusion- Disinfection, storage time, pigments and opacifiers influence various properties of silicones but most of them remain within the clinically acceptable ranges. Interaction between these factors should be understood and accordingly the materials and additives are to be chosen.

INTRODUCTION

Maxillofacial deformities either congenital or acquired can cause social withdrawal of an individual. In such cases, a maxillofacial prosthesis is a boon for them to resume a normal social life. The most recent and commonly used material for its fabrication is silicone. Silicone was introduced in maxillofacial prosthetics during 1960s (Goiato *et al*., 2010). The advantages are its excellent physical properties and ease of handling but like other materials, it has its own disadvantages like colour instability, changes in physical properties with time or under the influence of disinfectants, aging and poor shelf life. Various studies have been conducted to determine the effect of disinfectants and accelerated aging [simulating years of usage] on various properties of maxillofacial silicones with or without opacifiers and /or pigments. Dimensional stability is responsible for long term integrity of a prosthesis. It ensures proper fit and hence provides protection value. Detail reproduction by the material like wrinkles and sulcus gives esthetic value to the prosthesis.

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Tensile strength and tear resistance relate to prosthesis tearing while being used. Shore-A hardness provide information on texture and flexibility of elastomers which should be between 25-35 units (Dootz *et al*., 1994). The percentage of elongation is important in terms of elasticity. Pigments are added for esthetic reasons. Opacifiers increase material durability and keep it esthetically pleasant for a long time with respect to colour stability. It is imperative to protect the adjacent and underlying tissues from infection; hence chemical disinfection is of prime importance. During clinical use by the patient, the prosthesis is exposed to humidity, UV radiation, etc. Accelerated aging simulates the clinical usage. A review is presented on the effect of various factors on the dimensional stability, detail reproduction, mechanical properties and colour stability of maxillofacial silicones.

MATERIALS AND METHODS

Procedure

A PubMed search was done and studies were selected based on the inclusion and exclusion criteria. All the full text and abstracts were reviewed. No authors were contacted.

Search Strategy

A computerized database search using PubMed was conducted for peer-reviewed scientific research studies regarding the effect of disinfectants, aging, storage period, pigments and opacifiers on various properties of maxillofacial silicones, with no restriction for publication years. The search included only English language articles published in peer reviewed journals. The keywords used for the search were combinations of the following:

"Disinfectants, accelerated aging, artificial aging, outdoor weathering, pigments, opacifiers, nano-oxides, maxillofacial silicones, mechanical properties, dimensional stability, detail reproduction, hardness, colour stability, storage period, time".
A total of 123 titles were identified with the initial search. 70 were selected based on title and abstract. Of these after complete reading and discussion, 53 were selected according to the in clusion and exclusion criteria listed in Table I, all of which were in vitro studies.

Data retrieval and analysis

Data were obtained from all included studies and tabulated by dividing them under the headings *Dimensional Stability and Detail Reproduction, Mechanical Properties and Colour Stability* in the order: year, study, outline and summary in Table 2, 3 and 4.

RESULTS

From the literature review, it is deducted that dimensional changes produced due to disinfectants, aging, pigments, opacifiers are within the specified limits. There is no impact on detail reproduction of the maxillofacial silicone. Mechanical properties are affected adversely by disinfection and pigments but improved by nano-oxides at a proper concentration and storage period. Opacifiers protect the silicones from colour degradation. Accelerated aging causes dimensional changes, colour and brightness changes, crack formation and hardening.

Table 1. Inclusion and Exclusion Criteria

Inclusion criteria:	Exclusion criteria
Studies written English full texts availability	Studies not published in English Abstracts Studies related to elastomeric impression materials or acrylic resins

DISCUSSION

Dimensional stability

Anusavice has stated the five main reasons for dimensional changes in elastomeric materials: polymerization shrinkage, by-product release during condensation reactions, thermal shrinkage, sorption following exposure to water, high humidity environment for long period, disinfection, and incomplete elastic deformation recovery due to viscoelastic behavior (Goiato *et al*., 2010). Silicones exhibited dimensional changes with respect to time, disinfectants, aging, opacifiers and pigments (Goiato *et al*., 2010; Yu and Koran, 1979; Goiato *et al*., 2008; Guiotti *et al*., 2010; Haddad *et al*., 2011; Pesqueira *et al*., 2012).

- Time- According to the study (Pesqueira, 2012), time period is responsible for the highest dimensional change and is due to the continuous extended polymerization of elastomeric material followed by by-product release (Pesqueira *et al*., 2012).
- Disinfectants- The disinfectants and its type did not affect the dimensional stability significantly (Pesqueira, 2012; Goiato 2008; Guiotti *et al*., 2010).

Table 2. Dimensional stability and detail reproduction

Year	Study	Outline	Summary
1979	Yu & Koran [3]	Effect of accelerated aging on RTV[Silastic 382, 399, 44210], HTV [Silastic 44515] silicones, PVC- PrototypeIII and polyurethane- Epithane	Silicones were more stable than other elastomers under the conditions of accelerated aging
2008	Goiato et al [4]	Effect of disinfectant [Efferdent] and storage tim with respect to two maxillofacial silicone [Silasti MDX 4-4210 and Silastic 732 RTV silicone]	Disinfectant did not affect the dimensional stability and detail reproduction. Storage time had a statistical influence on dimensional stability. Silastic MDX 4-4210 had less contraction than Silastic 732 RTV.
2010	Goiato et al [1]	Effect of opacifiers[Barium sulfate and Titanium dioxide], chemical disinfectants [Efferdent, 4% CHX, Neutral soap] and accelerated aging with respect to Silastic MDX 4-4210 silicone	Opacifiers and aging altered the dimensional stability of maxillofacial silicones; no significant effect was seen by disinfectants. No influence was noted on detail reproduction.
2010	Guiotti et al [5]	Effect of storage period and chemical disinfection [4%CHX] on marginal deterioration of MDX4-4210 silicone with pigments[make up powder and iron oxide]	Silicone presented with marginal deterioration with time. No influence of disinfectant.
2011	Haddad et al [6]	Effect of disinfectants [Neutral soap, Efferdent and 4% CHX], accelerated aging, pigments and/or opacifiers[ceramic powder and/or barium sulfate] with respect to Silastic MDX4-4210 silicone	Incorporation of pacifiers and/or pigments, accelerated aging altered the dimensional stability. No effect of disinfectants was noted. No effect on detail reproduction.
2012	Pesqueira et al [7]	Effect of two disinfectants [Efferdent, neutral soap] and accelerated aging on Silastic MDX 4-4210 silicone with nanoparticles [make-up powder and ceramic powder]	Dimensional stability was influenced by 1008 hours of aging; no effect of disinfectants. Detail reproduction was not affected.

Table 3. Mechanical Properties

Year	Study	Outline	Summary
1980	Yu et al [8]	Effect of dry earth mineral pigment and accelerated aging on Silastic 4-4210 silicone	Most of the pigments decreased the physical and mechanical properties except shear strength of the silicone. Accelerated aging had no effect on the physical properties.
1980	Yu et al [9]	Effect of accelerated aging on physical properties of maxillofacial materials	Silicone elastomers demonstrated no change after accelerated aging, with best stability of HTV silicones
1992	Haug et al [10]	Effect of environmental factors on maxillofacial materials	Silastic 4-4515 was the strongest material tested and Type A Medical Adhesive was least affected
1994	Dootz et al [2]	Effect of accelerated aging on properties of 3 maxillofacial silicones	Aging decreased the tensile strength and percentage elongation, increased hardness
1999	Haug et al [11]	Effect of weathering	Weathering and time changes the physical properties of colorant-elastomer combination
1999	Lai and Hodges [12]	Effect of processing parameters	Avoid contamination of maxillofacial silicones during processing, stone molds degrades properties
1999	Haug et al [13]	Colorant effect on physical properties of silicones	Liquid colorants decreased hardness and tensile strength. Dry colorants increased hardness and decreased tensile strength
2008	Ying Han et al [14]	Effect of adding nano-oxides [titanium oxide, cerium oxide, zinc oxide] in the Silicone elastomers A-2186 at various concentration of 0.5% to 3%	2-2.5% by weight of nano-oxides improved the mechanical properties. Independent of the choice of the nano-oxide
2009	Goiato et al [15]	Evaluate Shore A hardness and surface roughness of MDX4-4210 AND Silastic 732 RTV silicones under the influence of chemical disinfectant [Efferdent and neutral soap] and storage time	Disinfectants had no significant effect on either hardness or roughness. Storage time increased hardness and decreased surface roughness
2010	Guiotti et al [16]	Evaluate Shore A hardness of MDX4-4210 silicone under the influence of pigments[make-up powder and iron-oxide], storage time [6, 12 months] and disinfectants [4% CHX]	Increase in hardness was seen from 0-6 months. Chemical disinfectants did not affect hardness in silicones with iron oxide. Utilization of pigments increased the Shore A hardness till not subjected to disinfection
2010	Goiato et al [17]	Effect of disinfectants [Efferdent, Neutral soap and 4% CHX], accelerated aging and opacifiers[barium sulfate and titanium dioxide] on maxillofacial silicone	Colorless group was not significantly influenced by chemical disinfection and accelerated aging. But with opacifier addition, both influenced statistically the hardness of silicone. The greatest variation was showed by the group with titanium dioxide. Greater hardness was demonstrated after 1008 hours of accelerated aging.
2011	Eleni et al [18]	Effect of outdoor weathering on Elastomer 42, TechSIL 25, M511 and an experimental CPE	Elastomer 42, TechSIL 25 became harder and more brittle
2011	Guo N and Jiao T [19]	Effect of adding surface organic modified nano-silicone-oxide in the concentration of 2%, 4% and 6% by weight on A-2186 silicone	Tear strength and hardness improved by adding the oxide in 2% and 4% by weight, with a decrease in tensile strength
2011	Hatamleh et al [20]	Effect of extra oral aging conditions	Adverse effect was noticed by human and environmental factors
2011	Polyzois et al [21]	Effect of time passage on silicones	Time passage contributes to overall deterioration of the silicone
2013	Eleni et al [22]	Effect of different disinfectants microwave exposure, sodium hypochlorite, neutral soap and a commercial disinfecting soap on hardness and color stability of PDMS and CPE	Disinfection altered the color and hardness significantly. Hardness was decreased after all the disinfection procedures for PDMS. The most suitable disinfection procedure suggested was microwave exposure
2013	Nguyen et al [23]	Effect of opacifiers and UV absorbers on pigmented MDX4-4210 maxillofacial silicone elastomer	UV absorbers degraded mechanical properties of the silicone when exposed to artificial aging
2014	Zayed et al [24]	Effect of surface treated silicone dioxide at various concentration	Significant improvement in mechanical properties as the concentration of silicone dioxide increased

- Accelerated aging- causes dimensional changes owing to the the photo-oxidative cleavage observed after absorption of UV light by the structure of most polymers which contain aromatic rings and C=C bonds (Goiato *et al.*, 2010; Pesqueira, 2012)
- Pigments and opacifiers- The incorporation of pigments/opacifiers alters dimensional stability [1, 6].Opacifiers increased the dimensional change owing to their high surface energy and chemical reactivity (Haddad, 2011).

Despite the increase in the dimensional changes, the silicone samples were within the standards recommended by ISO 4823, which states that the contraction should not exceed 1.5% after 24 hours [1] or ADA specification no.19, according to which contraction should not exceed 1% in 24 hours (Pesqueira *et al*., 2012; Haddad *et al*., 2011; Goiato *et al*., 2008).

Detail reproduction

There were no changes observed in the maxillofacial silicones regardless of disinfectants, aging, time, pigments and opacifiers (Goiato *et al*., 2010; Pesqueira *et al*., 2012; Haddad *et al*., 2011; Goiato *et al*., 2008).

Mechanical properties

Tensile strength

- Pigments- reduce the tensile strength, main effect by yellow pigment (Yu *et al*., 1980)
- Opacifiers- increase the property mainly by zinc oxide and titanium dioxide at 2% concentration (Han *et al*., 2008)
- Aging- showed no effect.

Table 4. Color Stability

Year	Study	Outline	Summary
1978	Craig et al [25]	Color stability of elastomers for maxillofacial appliances	Several silicone materials were the most promising with respect to color stability
1979	Koran et al [26]	Effect of accelerated aging on 11 pigments	7 of them demonstrated good color stability and 4 among them were less promising
1994	Bryant et al [27]	Influence of photo-protective agent [PABA and sunscreens with SPF-15] in color stability of silicones	None of the photo-protective agent provided UV protection and hence color stability.
1995	Lemon et al [28]	Effect of artificial vs. outdoor weathering on the pigmented silicone with an additive i.e. a UV light absorber UV 5411	Artificial weathering caused greater color changes than outdoor weathering. The addition of UV light absorber did not protect the silicone from color degradation
1998	Gary and Smith[29]	Pigments and their application in maxillofacial elastomers: a literature review	Color changes are to be expected when pigments are used with silicone elastomers
1999	Polyzois[30]	3 non pigmented silicones Silskin 2000, Elastosil M3500, Ideal were evaluated for color deterioration following outdoor weathering	All silicone elastomers showed visually detectable mean color differences
1999	Haug et al [31]	Effect of inorganic colorants [dry earth pigments, kaolin, artists' oil, liquid cosmetics] addition in the silicones	Stabilizing effect on the color when exposed to weathering. Organic colorant [rayon fiber flocking] was the least color stable
1999	Beatty et al [32]	Effect of oil pigments added intrinsically and extrinsically on color stability following UV exposure	Oil pigments made silicones susceptible to UV radiation. Extrinsic application of pigments were more color stable
2002	Kiat-amnuay et al [33]	Evaluate the effect of 4 opacifiers[Georgia kaolin powder neutral, kaolin powder calcined, Artskin white, dry pigment titanium white] at concentration of 5%, 10% and 15% on color stability of pigmented [red, yellow ochre, burnt sienna and mixture of pigments] silicone A-2186 subjected to artificial aging	The opacifiers did not protect the silicone at any concentration from color degradation. Pigments when mixed with 10% Artskin white was most color stable followed by 10% dry pigment titanium white. Red pigment demonstrated the maximum and yellow the least color change
2004	Tran et al [34]	Effect of an ultraviolet light absorber and a hindered amine light stabilizer	UVA and HALS retarded color changes in some circumstances
2005	Kiat-amnuay et al [35]	Color stability of dry earth pigmented maxillofacial silicone A-2186 subjected to microwave energy exposure	Red pigment had the most adverse effect on color stability
2006	Kiat-amnuay et al [36]	Effect of 5 oil pigments [no pigment, cadmium-barium red deep, yellow ochre, burnt sienna, , or a mixture of 3 pigments] and 5 dry earth opacifiers[Georgia kaolin powder neutral, kaolin powder calcined, Artskin white, dry pigment titanium white, Ti white artists' oil color] at concentration of 5%, 10%, 15% addition to MDX4-4210/ type A silicone before and after accelerated aging	Additives protected the silicone from color degradation. Dry pigment Ti white remained the most color stable
2009	Mancuso et al [37]	Effect of pigments [ceramic, cosmetic powder and iron oxide] on Silastic 732 RTV and Silastic MDX4-4210 after accelerated aging	Materials with/without pigments presented similar color alterations, cosmetic powder being most color unstable. Both silicones presented color instability.
2009	Mancuso et al [38]	Effect of accelerated aging and pigments [make-up powder, ceramic and iron-oxide] on Silastic 732 RTV and Silastic MDX4-4210 by visual method	All groups were color stable in the visual method, though aging had a negative influence
2009	Goiato et al [39]	Effect of two disinfectants [efferdent and neutral soap] and storage time on Silastic 732 RTV and Silastic MDX4-4210 silicone	Efferdent did not statistically influence the mean color values. Storage time statistically influenced the mean color values
2009	Kiat-amnuay et al [40]	1 silicone white pigment was used in addition to the above mentioned pigments and same set of opacifiers on Silicone A-2000[8]	Yellow silicone pigment presented with greatest color alteration.
2010	dos santos et al [41]	Effect of pigments and accelerated aging on resins and silicones	Pigments and aging induced color changes
2010	Han et al [42]	Effect of nano-oxides [cerium oxide, titanium dioxide, zinc oxide] on color stability of pigmented A-2186 maxillofacial silicones	1% nano cerium oxide, 2% and 2.5% titanium dioxide with mixed pigments exhibited least color change after aging. Yellow pigment affected color stability significantly with all three oxides.
2011	Goiato et al [43]	Effect of disinfectants [effervescent tablets, neutral soap, 4% CHX] and accelerated aging on MDX4-4210 silicone with opacifiers[barium sulphate, titanium dioxide]	Both disinfection and aging promoted color changes with CHX promoting greatest color alterations following aging. Regarding the opacifiers, barium sulfate was most stable
2011	Haddad et al[44]	Effect of nanoparticles and opacifiers following disinfection and accelerated aging	Disinfection alone did not cause color instability significantly, association of pigment and opacifier was more color stabilizing.
2011	dos Santos et al [45]	Influence of pigments and opacifiers on color stability of artificially aged silicones	Opacifiers protected silicones and oil pigments were stable even without opacifiers.
2011	Pesqueira et al[46]	Effect of disinfection [efferdent and neutral soap] and accelerated aging on color stability of colorless and pigmented [ceramic and make up powder] facial silicone	All factors [pigment, period, treatment] and their interaction were significant. The ceramic pigment presented greater color stability and make up powder the least. Neutral soap produces higher color changes.
2011	Hatamleh and Watts [47]	Effect of porosities on color stability of silicones after aging	Mechanical mixing under vacuum reduced pore size and percentages than manual mixing, thus enhancing color production and stability

……………………Continue

2013	Bankoglu et al [48]	Influence of pigments and pigmenting methods were evaluated after 1 year of dark storage	Pigments and pigmenting method affected the color changes of different maxillofacial elastomers. The lowest color alteration was seen in white and brown colors and highest in red, yellow and non-pigmented groups. Highest color changes were noticed in intrinsically pigmented group.
2013	Kantola et al [49]	Effect of thermochromic pigment on color stability	No stabilization in color was observed
2013	Han et al [50]	Effect of opacifiers and UV absorbers on pigmented MDX4-4210 maxillofacial silicone elastomer	All opacifiers especially light protecting agent protected pigmented silicone
2014	Bangera et al [51]	Evaluation of varying concentration of nano-oxides [zinc oxide and titanium oxide] as ultra-protective agents when incorporated in Cosmesil M511 elastomer	Zinc oxide in lesser concentration provided more significant and consistent protection
2015	Akash et al [52]	Effect of incorporation of nano-oxides on color stability of Cosmesil M511 elastomer subjected to outdoor weathering	Nano oxides improved the color stability with Zinc oxide being more stable
2015	Al-Harbi et al [53]	To compare the effect of weathering in a hot and humid climate on mechanical properties and color of 3 maxillofacial elastomers [TechSil S25, MED-4210, A-2186]	Outdoor weathering adversely affected the properties of silicones. TechSil S25 was superior than the other two
2015	Sethi et al [54]	Effect of investments in molds of different materials [dental stone and die stone with three separating media namely alginate based, soap solution and die hardener] on color of maxillofacial prosthetic silicone elastomer [Technovant]	Die stone showed the most color change and die hardener the least. The best combination was dental stone [green] with alginate based separating media

Table 5. Colorants [36, 40, 54, 31, 29]

Organic	Inorganic
Animal, vegetable or synthetic origin	Mineral origin
Not stable due to double or triple bonds which imparts color	Stable due to ionic bond
	Difficult to use in pure form, vehicle added to make its use easy making it impure
Eg- rayon flocking fibers, cosmetic powder,etc.	Eg- iron oxide, ceramic powder, dry mineral earth pigments, etc.

Table 6. Silicones investigated till 2015

SILICONE BRAND	STUDIES
MDX4-4210	1,2,3,4,5,6,7,8,9,10,11,13,15,16,17,25,26,27,28,31,36,37,38,39,41,44,45,46,49,50
A-2186	2,10,11, 12,13,14,24,31, 32, 33,34,35, 42, 53
TechSiL S-25	20, 18, 47,53
MED-4210	53
Cosmesil M 511	2,18,48,51,52
Type A adhesive	10,11,13,28, 31,32
Cosmesil M522	48
MultiSil epithetic	22,48
Silastic 732 RTV	4,15, 37,38,39
Silastic 382	3,9, 25
Silastic 399	3,9, 25
Silastic 44515	3,9, 10, 25
Silastic A-102	10
Technovant M511	54
Ideal	30
Silskin 2000	30
Elastosil M3500	30
Silasto 30 and Premium 2	21
Elastomer 42	18
Silastic A-2000	40

Shear strength

- Pigments- increases it except yellow and ochre-yellow.
- Aging- no effect was noticed.

Hardness

- Pigments- liquid colourants and dry earth pigments have been shown to decrease hardness. Rayon fibres increase it (Haug *et al*., 1999).
- Opacifiers/Nano oxides- increased the hardness values. ZnO>TiO2>CeO2 (Han *et al*., 2008).
- Aging- Aging improves the hardness, suggesting that by the end of aging period, the material reaches a higher degree of polymerization (Goiato *et al*., 2009; Goiato *et al*., 2010 and Eleni *et al*., 2013).
- Disinfection- did not alter the properties significantly in silicones but with pigments and opacifiers addition, a decrease in the property was noted. This can be attributed to its interaction with the fillers and interference with the polymerization process (Goiato *et al*., 2009; Guiotti *et al*., 2010; Goiato *et al*., 2010).
- Storage- Proper storage of the silicone materials improves its hardness owing to continuous polymerization.

Percentage elongation

- Pigments- Rayon flocking fibres decreases while liquid colourants increases the elongation in the maxillofacial silicones (Haug *et al*., 1999).
- Opacifiers/nano-oxides- An increase was noticed.

Tear strength

- Pigments- No statistical difference except by artist oil pigments on adhesive type A was noted.
- Opacifiers/nano-oxides- increase was noticed mainly with Titanium dioxide at 2% conc.

The decrease in hardness, tear strength, tensile strength, percentage elongation as observed in the studies (Yu *et al*., 1980; Lai *et al*., 1999 and Haug *et al*., 1999) after the addition of pigments can be attributed to the following reasons:

- Physical interaction between the polymer and the pigment, instead of reinforcing chemical origin (Yu, 1980).
- Introduction of impurities by these pigments, thus reducing curing (Lai *et al*., 1999).
- Non-bonding of the fillers to the silicone resin matrix, thus degrading its physical properties (Haug *et al*., 1999).

Though a study showed an increase in hardness of the silicone after adding pigments owing to the rigidity of the pigment (Guiotti *et al*., 2010). Addition of nano-oxides in the silicone improves the mechanical properties. At a concentration of 2-2.5%, it improves the properties owing to its uniform distribution within the matrix and maintenance of original size. Beyond 3%, the particles agglomerate and degrade the property. But surface treated filler apart from increasing the filler-polymer interaction, improves the dispersion of the filler by reducing the agglomeration (Yu, 1980; Lai, 1999; Bryant *et al*., 1994; Gary *et al*., 1998). Considering the processing parameters, silicones cured in stainless steel molds exhibited significantly higher mechanical properties than stone molds. Curing at 67 degrees Celsius did not differ significantly from curing at 100 degrees Celsius. Special care must be directed towards any impurities incorporation during curing, which might interfere with polymerization (Lai, 1999).

Colour stability

Colour instability in the maxillofacial silicones has been attributed to the chemical alterations in the silicone, by discolouration of pigments that are not UV-resistant, stains accumulation, water absorption, infiltration, surface roughness, etc. Delta E greater than 3 is detectable by the human eye (Goiato *et al*., 2011).

Pigments- Studies (Kiat-amnuay, 2009 and Kiat□amnuay., 2002), have reported higher colour changes in the pigmented silicones when compared to non-pigmented ones. The amount of colour alteration produced by the pigments depends upon their physical and chemical properties i.e. inorganic/organic, particle size. Considering the chemical properties, inorganic pigments like ceramic powder, iron oxide are more colour stable than organic pigments, Table V. When using rayon flocking fibres, colour changes should be expected but there is no suitable alternative to it for mimicking surface blood vessels and telangiectasia. With regard to size of pigments particles, smaller sized pigments are more colour stable as they tend to aggregate thus providing reinforcement and are not easily removed following disinfection unlike larger sized particles which separate from the polymer (Pesqueira *et al*., 2011). For pigments like iron oxide, ceramic powder, cosmetic powder; the latter being organic and having larger particle size had shown more colour instability than the other two with spectrophotometer, though the visual perception test did not produce any noticeable changes when using these pigments (Mancuso *et al*., 2009; Goiato *et al*., 2009). A few studies have explained the protective effect of pigments like artists oil to bear result of blocking the light radiation (Kiat-amnuay *et al*., 2006; Haug, 1999 and dos Santos, 2011). The comparative evaluation of certain pigments reported higher chromatic changes with respect to artists oil and liquid cosmetics owing to the vehicle used or to the chemical incompatibility with the elastomers (Kiat-amnuay *et al*., 2009; Kiat□amnuay *et al*., 2002). With silicone pigments, yellow pigment has shown the highest change which was reduced significantly on mixing with red and burnt sienna. Use of 10% and 15% Artskin white, Ti white dry pigment as opacifiers is suggested when using these pigments. With dry earth pigment (Kiat□amnuay *et al*., 2002), red colour showed the increased colour changes, with yellow ochre being the most colour stable.

Opacifiers- protect the silicones from colour degradation by blocking Ultravoilet-B and avoidance of degradation of the elastomeric matrix and pigments (Han *et al*., 2013; dos Santos *et al*., 2011). Nano-oxides like titanium dioxide, barium sulphate, zinc oxide have the capacity to accomplish strong union with the polymeric chain of the silicones (Bangera and

Guttal, 2014; Akash *et al*., 2015; Haddad *et al*., 2011). These oxide also aid in avoiding pigment removal following repeated disinfection hence colour stability. The size of these particles is extremely important for blocking solar radiation. Zinc oxide(<50nm) showed better protection than titanium dioxide (<100nm) owing to its better dispersion by being smaller in particle size and its concentration (Akash *et al*., 2015). Among dry earth opacifiers, dry pigment titanium white appeared to be the most colour stable (Kiat-amnuay *et al*., 2006; Kiat□amnuay *et al*., 2002; Kiat-amnuay *et al*., 2009) followed by kaolin powder calcined, Georgia kaolin. Addition of organic Ultaviolet light absorbing agents such as PABA, UV-5411 was not found to be protective against aging. Adding Ultaviolet mineral based agent protected the silicone from colour degradation (Han *et al*., 2013). Extrinsic colouration has been shown to reduce the incidence of discolouration in maxillofacial prosthesis. But the studies related with this respect are limited (Goiato, 2011).

Chemical disinfection- Alkaline peroxides, Chlorhexidine, Neutral soap produced colour changes.Chlorhexidine exposes the opacifiers which if accompanied by aging deteriorates the colour. Neutral soap removes the pigment from the superficial layer of the silicone by digital friction and alkaline peroxides by oxygen release mechanisms thus promoting colour alterations (Goiato *et al*., 2011; Goiato *et al*., 2009). Among all the disinfectants tested, neutral soap has shown the highest and alkaline peroxides the least colour changes (Haddad *et al*., 2011; Pesqueira, 2011). The choice of disinfectant depends upon the pigments and opacifiers being incorporated in the silicone. When larger sized particles are used, neutral soap tends to contribute more in the chromatic alteration. In cases where organic pigments are used, peroxides by their mechanism of action can promote colour changes (Pesqueira, 2011). Aging- causes colour and brightness changes due to the photo-oxidative cleavage as stated earlier (Goiato, 2010; Pesqueira, 2012). An important aspect of types of maxillofacial silicones has not been reviewed in this study as the aim was to see the impact of various factors on silicones in general. The various types of silicones might interact with pigments, opacifiers, disinfectants in a slightly different manner, which can decide the type of additives to be used. The selection of a particular silicone is not only dependent upon the opacity desired, method of polymerization but also on its interaction with the factors mentioned herein (Craig *et al*., 1978). So a clinician must keep in mind during selection of a maxillofacial material the benefits and shortcomings of each material used in fabricating a facial prosthesis, thereby improving the success rate of prosthesis. Various silicones used in the articles reviewed have been presented in Table VI.

Conflict of interest: The authors have declared that no conflict of interest exists.

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