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RESEARCH ARTICLE

ANALISYS OF TEMPERATURE CHANGES DURING LIGHT POLYMERIZATION OF RESIN MODIFIED CALCIUM SILICATE CEMENTS

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Abstract

Resin-modified calcium silicate cements belong to the fourth generation. This type of material is a combination of calcium silicates and resin. They are hardened by two types of reactions: light polymerization and hydration. Parameters related to temperature increases during light polymerization were analyzed. The main factors affecting the amount of generated heat are the type of light sources (LS), the light intensity of LS, the position of LS, the distance between the material surface and LS, the composition and transmission properties of hybrid material, curing time, remaining dentin thickness and the thickness of the layer of hybrid CSCs. Different methods of measuring temperature changes are criticall discussed.

Introduction:-

Many different procedures and materials in dental clinical practice are associated with a significant increase in temperature. A high temperature generated in the direction of the dental pulp poses serious risks for irreversible changes in it. Protection of the dentin/pulp complex is an important factor in maintaining pulp vitality. This also includes preventing the transmission of temperature irritants in the direction of the dental pulp. In this regard, properties such as thermal conductivity and thermal insulation are extremely importantл (Saitoh M, et al 2004) Thermal conductivity measures the ability to conduct heat. Heat transfer takes place at a lower rate in materials with low thermal conductivity Thermal conductivity is a quality of the material that does not depend on the layer thickness, but only on the chemical composition of the material (N. Burger et al 2016) Very important factor is a composition of the material. The differences in the composition of the ratio of organic and inorganic components significantly affect thermal conductivity, and thermal insulation. Thermal conductivities of organic materials are generally lower than those of inorganic materials [Singh A,et al. 2005).

The molecular weight of the monomers is also important factor. Low molecular-weight monomers are known to produce higher exotherm reaction, as well as higher shrinkage, when compared with high molecular-weight monomers.(Kanchanavasita et al. 1996) It is important that the materials used, near the dental pulp or in direct contact with it, do not conduct heat and have thermal insulating properties..(Saitoh M,et al .2004.)

Dental pulp (DP) is a loose connective tissue that is richly innervated and blood supplied. Pulpal blood flow helps maintain pulpal temperature by providing circulation and absorbing or providing heat (Xu HHK,.et al.1997). Pulp microcirculation plays an important role in elimination temperature increases when the pulp tissue is affected by a thermal stimulus.

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Materials and Methods:-

The Literature searching methodology

A literature search base was undertaken in three electronic databases:PubMed, Ebscohost and Google Scholar for the period 2015-2024.The following key words have been used: resin modified calcium silicate cements, direct pulp capping, temperature rise.

Results and Discussion:-

The materials, especially those used as means for direct and indirect pulp capping must have the qualities of thermal insulators. Such modern bioactive materials are calcium silicate cements. Resin-modified calcium silicate cements (RMCSCs) belong to the fourth generation of them. This type of material is a combination of calcium silicates and resin. RMCSCs are materials, that are hardened by two types of reactions: light polymerization and hydration. The hydration process is slow because the reaction requires moisture. Hybrid material is a one-component paste that hardens after light polymerization for 10, 20 or 40 seconds according to the manufacturers(Bisco, Schamurg,; Harvard Dental International, Germany.). The presence of organic components such as different types of monomers in the composition of hybrid CSCs can have a negative impact and lead to unsatisfactory clinical effectiveness. One reason for this is probably due to the free unpolymerized monomers. And free monomers may diffuse into the dental pulp and cause a detrimental effect (C. Jeanneau et al .2017; Bakhtiar,et al , 2017) . However, insufficient light intensity accompanied with insufficient light curing time, can lead to poor polymerization and incomplete conversion of monomer, especially in deeper parts of the cavity. Consequently, non-reacted monomer present in the resin can be released, which can be harmful for vital pulp tissue (Loney RW, Price RB, 2001). The degree of conversion of monomers from the composition of hybrid CSCs is related to the final mechanical properties (J. Yang, J et al. 2020; R. Stencel, et al. 2018). The free unpolymerized monomers negatively influence mechanical properties of the material (E. Sonkaya, et al. 2020) A high degree of conversion ensures good physical-mechanical properties of hybrid material, but on the other hand, it leads to higher polymerization shrinkage and polymerization stress (. Ilie N,.et al. 2005; Knezevic.et al.2005).

The degree of conversion is usually higher with a high intensity of the lamp and longer polymerization time is used. Both factors are responsible for higher temperature rise (Tarle Z et al. 2006.)

Important parameters for assessing the efficiency of different curing lamps are the degree of conversion and increase in temperature during photo polymerization of dental materials. Both mentioned parameters are dependent on the light intensity emitted from the curing unit, spectrum of wavelength as well as curring time(Knežević et al. 2008)

The main factors affecting the amount of generated heat are the type of light sources (LS), the light intensity of LS, the position of LS, the distance between the material surface and LS, composition and transmission properties of hybrid material, curing time, remaining dentin thickness and the thickness of the layer of hybrid CSCs (Kuo WC,. et.al.2011) The temperature could be originated from both the exothermic polymerization of the material and the energy absorbed from the light curing unit (LCU). Studies have shown that the type of LCU used is also a crucial factor affecting the amount of the generated heat (Hannig M, Bott B., 1999)The light emitting diode (LED) is the most commonly used light sources in the clinical dental practice. LED curing units use electroluminescence to produce light, which produces more useful light with minimal production of heat. Newer generations of LED curing lamps offer a wide range of polymerization programs, a higher intensity, and a higher degree of conversion. However, they create conditions for an increase in temperature during the hardening of the material. (. Ilie N,et al. 2005.). LED light curing lamps with intensities above 2000 mW/cm^2 are widely used, and the heat generated by them creates an important clinical problem (Park SH, et al. 2010).

The distance between the tip of the light source and the restorative material is a crucial parameter, because it significantly influences the depth of polymerization reaction(G Corciolani , et al.2008)

Increased distances between the tip of the LS and the surface of the material can lead to incomplete polymerization (AW. Bennett, DC.Watts,2004) It was found that the distance of 2 mm from the tip of the LS to surface of the pulp capping material -TheraCal LC did not increase the temperature during polymerization (S. Savas, et al. 2014)

Pires et al reported that at 2 mm distance from the tip of the light guide the power density dropped to 78% of the original power density; at 6 mm distance the power density was down to 47% of the original power density. (Pires

JA, et al. 1993) In contrast, Prati et al found, that 2 mm away from the light guide, the power density was up to 61% of the output; while 6 mm distance it accordingly reaches 23% of the original power density (Prati C,.et al.1999) Therefore, it is important to determine how different distance from the tip of the ligh curing lamp affects the power density and the degree of conversion a

The increase in curing time from 20 to 40 seconds led to a decrease in residual free monomer content (K.Tanaka, et al.1991). However, the increase in curing time during polymerization of light cured calcium silicate cements could lead to harmful influence on dental pulp by the heat generation (SR.Smail,et al. 1988) So, the heat generated during the polymerization could lead to irreversible pulpal damage. To achieve complete polymerization, the thickness of the layer of hybrid CSCs should be small enough, about 0.65 mm. according to Nilsen, B et al (BW. Nilsen, et al. 2017) According to literature data, full polymerization of TheraCal LC requires a layer thickness of 2 mm, and for Bright MTA the appropriate layer thickness is 2.1 mm (P. Sung-et al. 2021). According to the manufacturer, the thickness of the layer of TheraCal LC should be 1 mm and it polymerizes in 20 seconds (Bisco, Schamurg). Gandolfi et al. (Gandolfi MG et al. 2012) reported the appropriate TheraCal layer thickness to achieve full polymerization is 1.7 mm.

The degree of conversion is usually higher with a high intensity polymerization program and longer polymerization time is used. Unfortunately, both factors are responsible for higher temperature rise (Tarle Z,et al. 2006).

All LCU devices were found to generate high temperature changes and to cause harmfull effects in the dental pulp (Nilsen, et al. 2020;Price R.2018). There are studies that the use of LCU leads to an increase in temperature in the direction of the dental pulp (Yazici AR et al.2006)

The peak light temperature of the light-cured lamp was found to be 53.61±0.93 °C for 10 s exposure and 58.97±0.93 °C for 20 s exposure, respectively. (Petrovic, et al. 2019). The temperature rise depends on the duration of the light polymerization and the use of high intensity sources. The temperature rise varies depending on the type of the materials used. (L.Szalewski, et al. 2021)The exothermic type of polymerization of the material is the secondary factor(Lloyd CH,. et al.1986).

Several methods have been applied for measuring the temperature rise in pulp tissues, such as thermocouples, differential thermal analysis, differential scanning calorimetry, and infrared thermal camera (A. Vinagre et al. 2019; Xin Er Lau et al 2023). Thermocouples are a widely used method for measuring heat generation or measuring heat transfer across the tooth structure. It has been claimed that system errors of less than 1°. (Goldberg MP.1965) Measurements of heat generation and related temperature change can also be afected by the position of the thermocouples placed, as a change in location of the probe (Dias M,.et al 2019)

Little information is available in the literature regarding the generation temperature and degree of polymerization of hybrid calcium silicate cements. As available data only applies only for TheraCal LC but not to the newly introduced into practice hybrid pulp capping materials.

In comparison study, light activation of all the pulp capping materials and composite have shown increase in pulpal temperature but not beyond the critical value of 5.6°C. TheraCal has shown lowest temperature rise in pulp chamber compared to other light curing $Ca(OH)_2$ based pulp capping materials(Lakhani J. et al. 2018)- TheraCal LC had the lowest mean temperature increase of all the other pulp capping materials, independent of distance factor. The reason for the low temperature increase with TheraCal LC might be because its content is different from the other materials(S. Savas, et al. 2014)

In contrast other authors (D. Oliveira, et al. 2022), are found the intra-pulpal temperature increased at Dycal (Denstsply), Vitrebond (3M); and TheraCal (Bisco). approximately 10^{o} C to 20^{o} C.. As the results show, both liners tested (Dycal and TheraCal LC) did not provide sufficient thermal insulation after light-activated procedures. The average power of the LED curing light used in this study was 1009 mW/cm^2. In this comparative study it was found that only Biodentin has the quality of a thermal insulator. Dycal's main ingredient is calcium hydroxide, while TheraCal LC is a resin-modified calcium silicate designed to cure with light. The main purpose of the Liner is to protect the pulp and accelerate the formation of a reparative dentin bridge. (Savas S,.et al. 2014; Saitoh M,.et al. 2004)

Only one study is available on the Degree of Conversion % of TheraCal. The Degree of Conversion % means of TheraCal LC- after LED-polymerization at 385–515 nm wavelength range at 900 mW/cm^2 20 sec.were 78.5% (G. Dikmen,et al..2023)

The data available in the literature are not conclusive and clearly indicate the need for in-depth research.

Depending on the clinical situation, it is up to the practitioner to adapt polymerization time and intensity, which ensures maximal degree of conversion and minimal negative effects of resin modified calcium silicate material photopolymerization.(A. Kneževićet al 2008)

Conclusions:-

The main factors affecting the amount of generated heat are the type of light source LS , the light intensity of LS, the position of LS, the distance between the material surface and LS, the composition and transmission properties of hybrid material, curing time, remaining dentin thickness and the thickness of the layer of hybrid CSCs. The high temperature could originated from both the exothermic polymerization of the material and the energy absorbed from the light curing unit (LCU). The degree of conversion of monomers is usually higher with a high intensity of the lamp and longer polymerization time is used. Both factors are responsible for the higher temperature rise. Depending on the clinical situation, the practitioner can adapt polymerization time and intensity, which ensures a maximal degree of conversion and minimal negative effects of hybrid material photopolymerization

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