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Review Article

Dental Fillings Materials and Dental Management against Hypersensitivity Reaction of Stainless-Steel Crown: A Review

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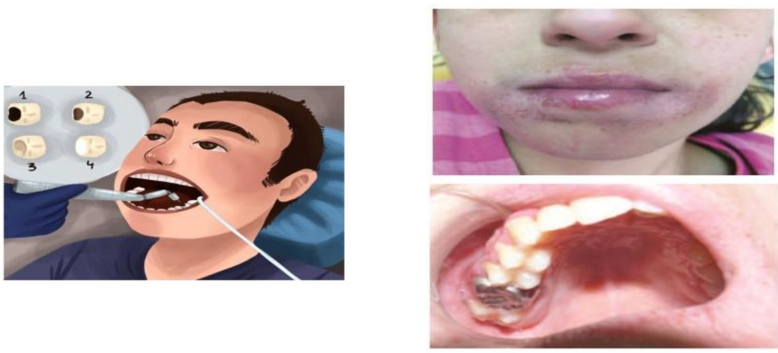
ABSTRACT

Tooth structure damage is usually caused by tooth decay or external damage. Dental fillings are one of the restorative dental treatments used to repair tooth fractures, tooth decay, or damage to tooth surfaces. Dental fillings include composite, porcelain, and silver amalgam, which are used on the tooth surface for better biting and chewing. The aim of this literature review is to assess the merit of stainless-steel crown, the shortcoming of stainless-steel crown, and the hypersensitivity reaction and dental management against hypersensitivity reaction of stainless-steel crown. The method used in this study was by reviewing international journals related to hypersensitivity reaction against stainless-steel crown. The results of this literature review showed that stainless-steel crown had advantages such as good physical properties, less sensitivity to moisture, and less prone to fracture; nevertheless, it had disadvantages such as unstable in acid pH and drastic change of temperature, which led to the release of a metal ion such as nickel into the oral cavity and the emergence of hypersensitivity reaction. The treatment that can be done for hypersensitivity reaction was by doing a patch-skin test before treatment and restoration replacement with non-toxic material. This review can be applied as a consideration on determining restorative treatment, especially in pedodontics restorative treatment.

GRAPHICAL ABSTRACT

Dental fillings materials and dental management against hypersensitivity reaction of stainless-steel crown: A review



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Introduction

Decayed teeth need repair and treatment. Otherwise, tooth decay becomes more severe and requires more serious treatment. Your dentist will usually recommend a tooth filling to repair a decayed tooth by removing the rotten part and then filling that area with special materials. Dental fillings can also be used to repair cracked, broken teeth or teeth that have eroded with bruxism. Tooth decay has no specific age [1-4]. Tooth decay can occur at any age and for all teeth. Also, tooth decay is usually caused by poor oral hygiene. In this case, the person should go to the dentist for treatment of their decayed teeth and fill their teeth [5, 6].

Caries are a destructive disease of localized hard tissue of the oral cavity that is often found in the community, especially in children [7, 8]. Destruction in the hard tissue of the oral cavity is caused by the activity of cariogenic bacteria that produce acid [9, 10]. The final product of bacteria in the form of acid can change the pH of the mouth to become more acidic so that it can cause destruction of the teeth. The condition of the oral cavity with an acidic pH that continues without any action to change the pH of the oral cavity can lead to continuous progressive destruction. This continuous digestion causes caries. Caries can occur all over the tooth surface. Long-standing caries can certainly expand and involve the entire tooth surface. One of the main caries treatments in primary teeth is to perform restoration with Glass Ionomer Cement. However, restorations with this material have the disadvantage of having low mechanical properties, especially when it is used on posterior teeth, which require large chewing pressure. One of the alternative treatments that can be done to restore posterior primary teeth is to use a Stainless-steel Crown (SSC) material [11, 12].

Stainless steel crowns (SSCs) were first used as restorative materials for primary teeth in 1950, and until now, this material is still often used to restore posterior primary teeth with extensive cavities. In addition to restoring teeth with large cavities or carious lesions, this material is often used to restore teeth after pulpotomy or pulpectomy, restore fractured posterior primary teeth, restore primary teeth that have been abrasion, or eroded, and can be used as an abutment space maintainer [13].

The constituent components of SSC consist of 76% nickel, 15% chromium, 8% iron, 0.35% manganate, and 0.2% silicon. Metal elements are the most dominant constituent of SSC so that this material has the advantage of having good physical and mechanical properties so that it can be used for posterior tooth restorations, can be completed in one visit, is not prone to fractures, is not sensitive to moisture, and is relatively inexpensive1. Besides having advantages, this material has a weakness: It can cause hypersensitivity reactions due to the metal content in SSC, especially the nickel content. Studies show that hypersensitivity reactions due to SSC materials not only cause reactions in the oral cavity but cause reactions in the perioral area [14]. The problem of the hypersensitivity reaction of SSC material due to its metal content cannot be ruled out because it can have a negative impact. If these impacts arise, they will require countermeasures. Therefore, this literature review would discuss studies related to SSC materials and their contents as well as hypersensitivity reactions that can be caused by a metal content in SSC and actions that must be taken before and after restoration considering that SSC will be in the oral cavity for a long time, about 8-9 years until the permanent replacement tooth erupts [15].

Literature Review

Stainless-steel Crown (SSC)

A stainless-steel crown is one of the dental materials that are often used in the case of dental restorations in children with extensive cavities. Stainless steel crowns began to be used as restorative materials in paediatric cases in the 1950s to treat caries in primary teeth involving more than two surfaces. Non-precious metals are the main constituent components of stainless-steel crowns consisting of 76% nickel, 15% chromium, 8% iron, 0.35% manganate, and 0.2% silicon [11, 14].

Stainless steel crowns are often used to restore carious primary molars involving more than two surfaces. In addition, stainless-steel crowns are often used in post-endodontic treatment in children and can also be used to restore teeth with developmental anomalies such as dentinogenetic imperfecta, amelogenesis imperfecta, and others. Patients with a high risk of caries can also use stainless-steel crowns. This material can also be used to restore molar teeth that have fractured, abrasion, erosion, and protect teeth that experience an extreme surface structural loss, such as in the case of attrition. However, this restoration cannot be used when the primary molars are nearing the exfoliation period or when the roots of the primary molars have undergone more than half of the root resorption. This material can also not be used in patients with nickel allergies or the metals contained in stainless-steel crowns [11, 13].

There are three types of stainless-steel crowns, namely untrimmed crowns, pretrimmed crowns, and preontoured crowns. Untrimmed crowns are stainless-steel crowns that have not been trimmed and contoured, so they require a lot of adaptation and take more time. One type of stainless-steel crown is Rocky Mountain. Pretrimmed crowns are stainless-steel crowns that have perpendicular sides and have not been contoured but already have a surface parallel to the gingival crest and still require contouring and trimming. An example of this type of SSC is Unitek. Precontoured crown is an SSC that has been adjusted to the contour of the gingival crest and has been contoured so that it requires minimal trimming and contouring. An example of this type of SSC is a Ni-Cr crown. In carrying out the contour and trimming process, there are several tools used to assist the process, including the bur and plier consisting of Johnson 114 Contouring to form the overall contour, crimping plier 417 to mark the cervical curvature, and Gordon 137 to shape the contour and forming the SSC itself [13].

Advantages of Stainless-steel Crown (SSC)

Stainless-steel Crown is a restoration material with metal alloy as its main component. This gives them better physical properties and durability than amalgam restorations [16]. SSC also has a "full-coverage" concept that protects the entire tooth surface. The concept of "full-coverage" also aims to eliminate the risk of tooth fracture, especially on the buccal and lingual surfaces due to a large reduction in dentin strength. This allows this material to improve caries prevention by protecting the entire tooth surface [17].

In addition, stainless-steel crowns have another advantage: They are well received by patients and doctors. Clinical procedures are also considered effective because this restoration can be done in one visit and does not require special laboratory procedures. Stainless steel crowns are also more resistant to moisture and risk fracture [11].

Disadvantage of stainless-steel crown (SSC)

There are several disadvantages of stainless-steel crowns that can occur, either during the preparation stage of the stainless-steel crown or after the stainless-steel crown is in the oral cavity. When in the preparation stage, some of the weaknesses that stainless steel crowns can cause include the interproximal ledge, crown tilt, poor margins, and ingestion of crown [13]. In addition, this disadvantage can also appear after stainless-steel crowns are used.

The disadvantage of stainless-steel crowns can also occur after the material has been installed and used in the oral cavity. In the oral cavity, there is saliva with a certain pH and temperature, which acts as a natural corrosive substance [18]. pH conditions can be more acidic or more alkaline than normal conditions. Likewise, the temperature of the oral cavity can change to be higher than normal conditions. pH conditions that are too acidic can lead to lysis of nickel ions from the stainless-steel crown into the oral cavity. In addition, conditions of temperature changes that are too drastic can also cause the same thing [14, 17, 19, 20]. This shows that the stainless-steel crown is sensitive to acidic pH and temperature changes that are too drastic because it can cause the release of ions that make up the stainless-steel crown, such as nickel, chromium, etc. into the oral cavity and then enter the digestive system and blood circulation. This can have a negative impact, namely the emergence of hypersensitivity reactions due to these materials. The existence of this impact certainly needs special attention, so that several studies have been conducted to evaluate the hypersensitivity due to the stainless-steel crown material. The hypersensitivity reaction due to SSC is shown in Figure 1 below.

Figure 1: Hypersensitivity reaction due to SSC in the perioral area [14]

Studies on the hypersensitivity reaction of stainless-steel crown (SSC)

Hypersensitivity reactions that occur after the installation of stainless-steel crowns are type IV hypersensitivity reactions [21]. The hypersensitivity reaction that appears is possible due to the presence of metal content in SSC, especially nickel. Various studies have been carried out to further review the hypersensitivity reactions that arise due to stainless-steel crowns.

The study of stainless-steel crowns was carried out on the basis of a case report showing that stainless-steel crowns caused hypersensitivity reactions in the perioral area. A woman complained of discomfort in the mouth after SSC insertion 13 years after SSC insertion. The results showed the presence of vesicles on the skin, perioral desquamation, non-exudative reddish areas with irregular edges, salivary pH, and normal salivary flow rate. In this case, the treatment was carried out by replacing the SSC material with acrylic. After evaluation, no perioral lesions were found. Due to SSC, hypersensitivity reaction lesions have a tendency to appear in the perioral area due to the amount of nickel dissolved in saliva more than the amount of nickel in contact with the mucosal area of the oral cavity. Based on this case report, various studies were conducted to evaluate hypersensitivity reactions to SSC.

Research on stainless-steel crowns has been carried out to see the various effects of stainless-steel crowns. One of the studies was conducted to see the nickel content lysed from stainless-steel crowns. The results showed that the amount of nickel released during the first day was higher than on the 7th day, then the amount did not experience an increase in the following days. This is due to the formation of an oxide layer on the SSC surface which can protect SSC from salivary corrosion. In addition, the more SSC appeared, the more nickel ions were released. Based on this research, the release of nickel ions was not influenced by how much nickel ion content was in the SSC but rather by the level of resistance of SSC to electrochemical corrosion by saliva [17, 22–25].

The research was also conducted to see the nickel lysis of the trimming process when adjusting the stainless-steel crown. The research was also conducted to determine changes in pH and temperature on the release rate of nickel in SSC. The assumption that emerged was that trimming would cause more nickel ions to be released because of the micromaterial that emerged as a result of the trimming process. However, the results showed that the presence of trimming did not cause an increase in nickel lysis. The amount of nickel lysed content was not influenced by the trimming action of the crown rather it was influenced by the surface area of the SSC crown. Changes in pH can affect the size of the amount of nickel lysis into the body. Acidic pH can cause metal ion lysis of a material. This was because an acidic pH affects the solubility level of metal materials. Changes in temperature that were too drastic in a short time can also affect the size of the nickel content being lysed [19].

Another study was conducted to see the absorption of nickel, chromium, and iron on the surface of the primary teeth molar roots, which were restored using stainless-steel crowns. This study aimed to compare the old generation nickel with a nickel content of 72% and the new generation nickel with a nickel content of 9% to the release of nickel ions. The results showed that the newest generation of nickel with less nickel content still released nickel ions into the body, which were then absorbed by the roots, as evidenced by the presence of nickel content in the dental cementum. After nickel exposure, blood vessel endothelial cells will produce cytokines within 24 hours. Nickel also acts as a signal for T cells to come to the site of exposure and triggers an inflammatory response by activating TLR4 so that an allergic reaction occurs. Nickel hypersensitivity varied, depending on the amount of nickel present and transported, and that distribution causes an active cellular response [20].

Stainless-steel crown (SSC) hypersensitivity reaction process

The process of the SSC hypersensitivity reaction occurs through the sensitization phase and the elicitation phase. The sensitization phase is the phase where exposure to ions that cause allergic reactions and recognition of allergens occur. This phase occurs for approximately five days. After that, there is a response to the allergen mediated by activated allergen-specific T Lymphocytes. This is called the elicitation phase, which occurs two days after the sensitization phase. Therefore, a hypersensitivity reaction takes place one week after the installation of metal materials such as SSC because, on the seventh day, there has been an elicitation phase [14, 26].

The molecular hypersensitivity process is described in some literature using an animal model by injecting nickel chloride, which is then evaluated. The hypersensitivity reaction process occurs after the nickel has penetrated the skin tissue. This will activate keratinocytes which cause the release of several cytokines such as IL-1β, TNF-α, and TSLP, which will induce activation and migration of haptenized proteins. Then, nickel ions (haptenized protein) attach to MHC (Major Histocompatibility Complex) in Langerhans Cells or Dendritic Cells. After nickel ions attach to Dendritic Cells, a Ni-activated epithelial Dendritic or Langerhans Cell will form, which will then trigger the formation of CD80, CD83, CD86, and MHC Class II [27, 28].

Nickel also plays a role in the maturation and activation of immature Langerhans Cell and Dendritic Cell via phosphorylated MKK6 (MAP Kinase Kinase 6). Dendritic cells that have matured will experience migration through afferent lymph nodes to draining lymph nodes. In the draining lymph node, there is the presentation of haptenized-peptide on naïve T cells. Secretion of cytokines in draining lymph nodes will lead to activation, proliferation, and differentiation of haptenized-specific T cells. Then, the T Cell comes out of the draining lymph node into the skin. In the elicitation phase, exposure by the same hapten will be taken back by the cells, which will then be presented back through the process of haptenized-specific T cell presentation. This repeated exposure will produce inflammatory cytokines and chemokines in the exposed area and will produce an allergic reaction, such as the appearance of several lesions with specific characteristics (Figure 2) [29].

Handling

There are several treatments that can be done in cases of hypersensitivity reactions to stainless-steel crowns. This treatment can be done before the hypersensitivity reaction occurs to prevent the reaction and can also be done after the hypersensitivity reaction appears. If the stainless-steel crown is chosen as the restoration material to be used, it is necessary to do a patch-test allergy prior to treatment. This aims to see whether the patient is allergic to the metal content in these materials, especially for female patients because women have a higher incidence of hypersensitivity reactions than men. Patch-test is performed using an adhesive plaster containing reagents and is placed on the patient's back or arm for 48 hours. After that, the plaster is removed and waited one hour to see a reaction on the skin. The evaluation is carried out using the ICDRG (International Contact Dermatitis Research Group) criteria [30]. The same is done again and evaluated for 72 hours one week later and observed after the adhesive plaster is removed then re-evaluated [31]. The presence of areas of erythema combined with the presence of edematous infiltration with or without papules and vesicles show a positive result on the test [32]. The ICDRG criteria used are shown in Table 1.

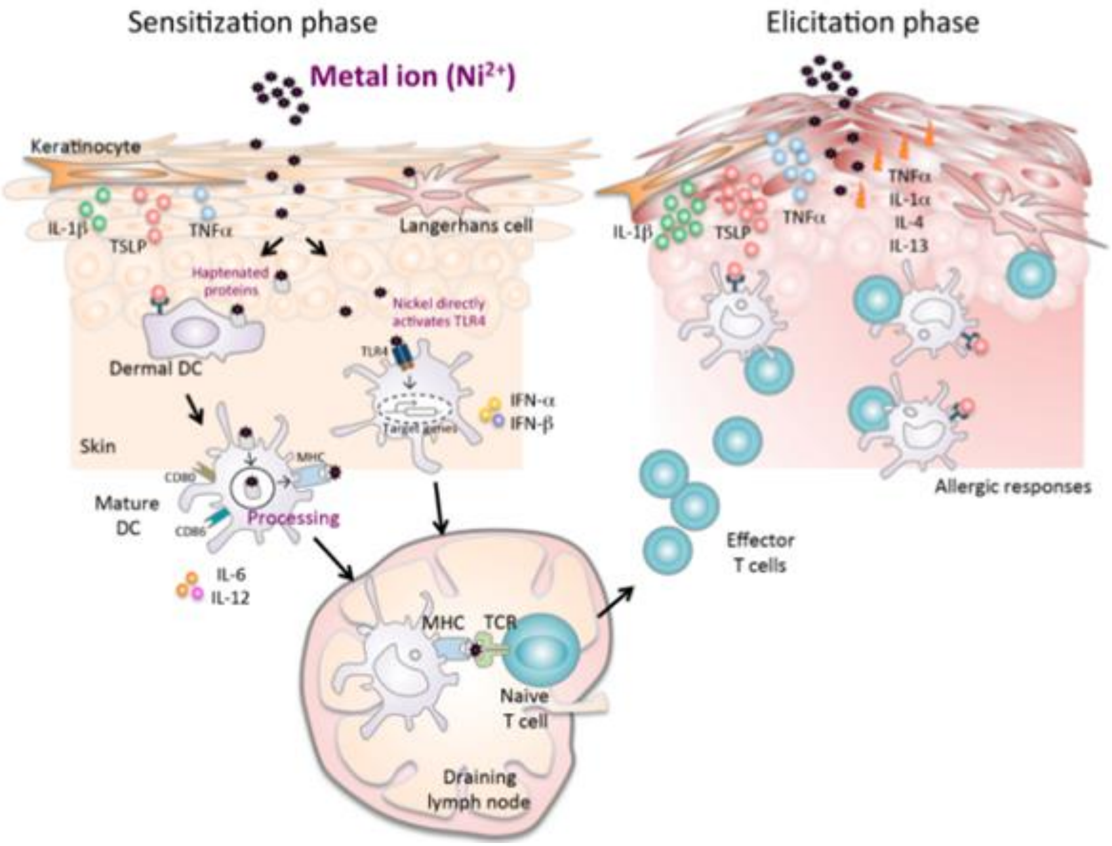

Figure 2: Hypersensitivity reaction mechanism molecularly [21]

Table 1: ICDRG Criteria

Symbol	Morphology	Interpretation
-	No reaction	Negative
?	Erythema only no infiltration	Doubtful reaction
+	Erythema, infiltration, possibly discrete papules	Weak positive reaction
++	Erythema, infiltration, papules, vesicles	Strong positive reaction
+++	Erythema, infiltration, confluent vesicles	Extreme positive reaction
Ir	Different types of reactions (scap effect, vesicles, blister, necrosis)	Irritant reaction
Nt		Not tested

Case handling can also be done if there has been a hypersensitivity reaction due to stainless-steel crowns. Handling can be done by removing restoration and reconstruction or re-filling using materials that do not cause sensitivity. One of the materials used to replace the stainless-steel crown is a bis-acryl crown which is cemented on the tooth using GIC. After installation, it is necessary to re-evaluate it after one week and six months of changing the material [14, 26].

Results and discussion

A Stainless-steel crown is a primary tooth restoration material whose main constituent consists of a mixture of metal elements such as nickel, chromium, iron, manganate, and others. Because it is composed of metal elements, of course, this material has good physical properties and has better longevity than other metal restorations such as amalgam, so that it is more durable. This material also has moisture resistance and is not prone to fracture, making it suitable for use in the restoration of posterior primary teeth that require large chewing strength [11, 13, 16, 17]. Behind its advantages, this material has several disadvantages.

The stainless-steel crown as a deciduous tooth restoration material has several drawbacks that need attention. When it is adapted to teeth, there are several possibilities that can occur, including interproximal ledge, crown tilt, poor margins, and ingestion of crown3. The stainless-steel crown is also more sensitive to acidic pH and too drastic changes in temperature. In the oral cavity, saliva acts as a natural corrosive material with a certain pH and temperature. When the stainless-steel crown is in the oral cavity, saliva will naturally hit the surface of the material. The existence of a pH that is too acidic and changes in temperature that are too drastic can make metal ions from the stainless-steel crown released into the oral cavity. When this happens, metal ion components can dissolve in saliva, carried to the digestive system and blood vessels, causing hypersensitivity reactions [17, 20].

Hypersensitivity reactions do not appear immediately when metal ions are released and enter the digestive system. The reaction occurs when entering the elicitation phase (one week after insertion). One week after the reaction occurs, an oxide layer will form on the surface of the SSC, which can inhibit the release of nickel ions into the oral cavity environment. The results of various studies also show that the more SSC is present, the higher the amount of nickel ions that can be released. In addition, the amount of nickel ion released is more influenced by the surface area of the material and the acidic pH and the temperature changes that are too extreme. The newest generation SSC with less nickel content also shows that nickel ions can escape into the oral cavity. The released ion is still in the low limit and does not enter the cytotoxic level, which is only 0.0269 ppm (toxic dose: 2.5 mg/ml). The amount of nickel released and entering the digestive system does not exceed the tolerance threshold of 200-300 μg per day. The toxicity and carcinogenicity of nickel are affected by uptake, transport, distribution, and retention at the cellular level. If the amount of nickel released is minimal, this certainly will not cause a toxicity reaction but still can cause a hypersensitivity reaction. This is possible because nickel has a high haptenic capacity, and there are individuals who are more sensitive to nickel. Individuals who are more sensitive to nickel have a higher leukocyte chemotactic response so that it can promote suppression and changes in DNA synthesis and enzymatic activity, which may lead to adverse effects such as hypersensitivity reactions [14, 17, 19, 20].

One thing that can be done to prevent hypersensitivity reactions from SSC is to carry out a comprehensive history taking if the patient is going to perform restorations with dental materials that can trigger an allergic reaction. This can prevent unwanted reactions from occurring [33, 34]. Patch-skin tests can also be done before performing restoration treatment. This can indicate whether an individual has a sensitive reaction to the metal content of a material. If SSC has been inserted and a hypersensitivity reaction occurs, SSC can be replaced with a material that is non-toxic and does not contain metal ions such as acrylic [14, 30].

Conclusion

Stainless steel crown is a material composed of metal as its main component. This material has strong physical properties but is sensitive to acidic pH and drastic temperature changes. This can cause the release of nickel ions into the oral cavity. The more nickel in the oral cavity, the more nickel ions are released. Apart from that, the surface area of the material also affects the amount of nickel that is released. The amount of nickel released does not cause toxic effects but can only cause hypersensitivity reactions. The reaction arises because of the high haptenic capacity of SSC's metal (nickel) content and individuals who are more sensitive to it. One thing that can be done to minimize the occurrence of hypersensitivity reactions to SSC is to carry out a comprehensive history taking related to the presence or absence of allergies either to dental or non-dentistry materials. Patch-test can also be done to determine whether or not there is sensitivity to metal materials in an individual. Substitution of materials with non-metallic materials can also be carried out if the reaction occurs after SSC has been inserted and used.

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Authors' contributions

All authors contributed toward data analysis, drafting and revising the paper and agreed to be responsible for all the aspects of this work.

Conflict of Interest

The authors declare that they have no competing interests.

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