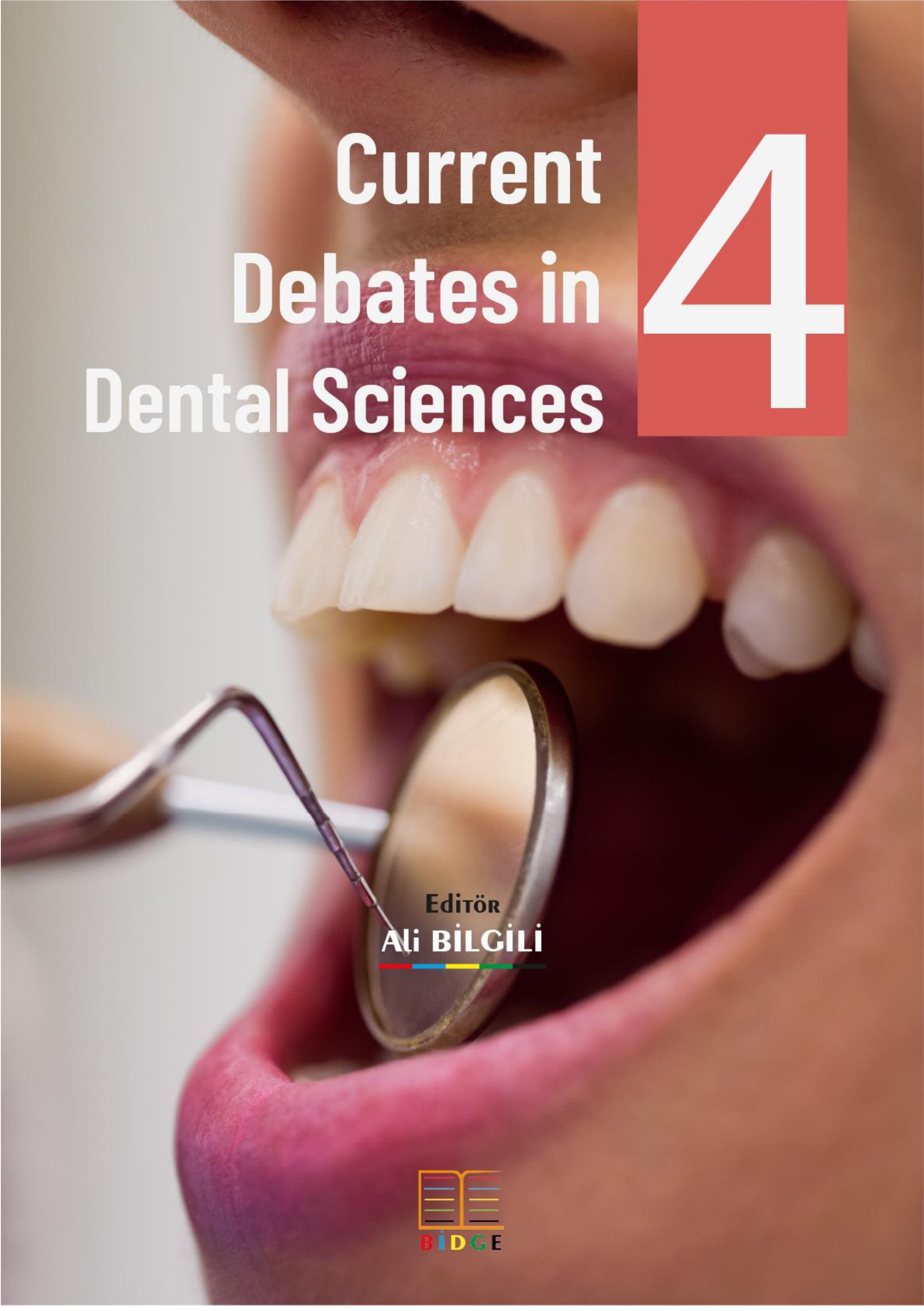
Current Debates in Dental Sciences 4



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www.bidgeyayinlari.com.tr - bidgeyayinlari@gmail.com

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Sodium Hypochlorite In Endodontics

Mügem Aslı EKİCİ
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Introduction

Endodontology is the 'branch of dentistry concerned with the morphology, physiology and pathology of the human dental pulp and periradicular tissues. Its study and endodontic practice encompass the basic and clinical sciences including the biology of the normal pulp and the aetiology, diagnosis, prevention and treatment of diseases and injuries of the pulp and associated periradicular conditions' (Glossary of Endodontics Terms, 2016). For the treatment of diseased root canals and/or periapical pathology endodontic treatment can be required. The main objectives of root canal procedures are adequate enlargement, shaping, cleaning, and disinfection of all pulpal spaces, along with obturation of these spaces with an acceptable filling material. Elimination of microorganisms from infected root canals is a complicated task due to the complex anatomy of root canals, consequently the information of common root canal morphology and its frequent variations is a essential requirement for success during endodontic treatment (Peters & Peters, 2016).

The aim of irrigation in endodontics are mechanical, chemical, and biologic. The mechanical and chemical aims are removal debris, lubricate the canal, dissolve organic and inorganic tissues, and prevent the formation of a smear layer during instrumentation or dissolve it once it has formed. The biologic objectives of irrigants include properties such as being highly effective against anaerobic and facultative microorganisms in their planktonic states and biofilms, inactivating endotoxin, being non-toxic when they come into contact with vital tissues and not causing anaphylactic reaction. For optimal disinfection, the preparation shape and antimicrobial efficacy are intimately related through the removal of infected pulp and dentin and creation of space for delivery of irrigants (Basrani & Haapasalo, 2012). Properties of ideal root canal irrigation solution are shown in Table 1. None of the available irrigation solutions can be regarded as optimal. To date, an ideal irrigating solution that possesses all of these desired properties does not exist even so the most commonly used irrigation solution in root canal treatment is still NaOCl.

History of NaOCl

Sodium hypochlorite (NaOCl) was first produced by passing chlorine gas through a solution of sodium carbonate, in 1789 in Javelle, France. The resulting liquid, known as “Eau de Javelle” or “Javelle water” was a weak solution of sodium hypochloriten (Basrani & Haapasalo, 2012).

Subsequently, NaOCl was recommended to prevent infectious diseases and childbed fever by Labarraque. As a result of controlled laboratory studies of Koch and Pasteur, NaOCl was later widely accepted as a disinfectant at the end of the 19th century (Zehnder, 2006).

In World War I, chemist Henry Drysdale Dakin and surgeon Alexis Carrel, based on studies that Dakin investigated the effectiveness of different solutions on infected necrotic tissues; expanded the usage area of buffered 0.5% NaOCl (Dakin, 1915). Walker first recommended using NaOCl in root canal treatment in 1936, then Grossman indicated that NaOCl has a tissue-dissolving capability in 1941. (Jena & et al., 2015). Spangberg (1973) stated that 0.5% of NaOCl has good germicidal activity. Coolidge (1919) later introduced NaOCl to endodontics as an intracanal irrigation solution. Beside their wide-spectrum and non-specific killing efficacy on all microorganims, hypochlorite preparations are both sporicidal and virucidal and also have much stronger dissolving effect on necrotic rather than vital tissues show far greater tissue (Valera & et al., 2009; Austin & Taylor, 1918). These properties of NaOCl enabled it to be used as primary irrigaiton solution in root canal treatment (Grossman, 1943; Zehnder & et al., 2003). In endodotics, NaOCl has a wide spectrum antimicrobial activity against difficult to eliminate microorganisms and biofilms. Moreover, NaOCl solutions are cheap, readily accessible, and have a long shelf life (Heling & et al., 2001; Mahmoudpour & et al., 2007). Other chlorine-releasing compounds such as chloramine-T and dichloroisocyanurate have been defended in endodontics, which however never obtained broad admission in root canal therapy and appear to be less efficient than NaOCl at similar concentrations (Zehnder, 2006; van Klingeren & et al., 1980).

Mechanism of action of NaOCl

When NaOCl contacts with tissue proteins, nitrogen, formaldehyde and acetaldehyde are formed within a short time. While peptide links are broken up to dissolve proteins, the hydrogen in the amino groups is replaced by chlorine-forming chloramines, which play a significant role in antimicrobial activity (Basrani & Haapasalo, 2012).

NaOCl exhibits a dynamic balance as shown by the following formula (Estrela & et al., 2002):

$$NaOCl + H_2O \leftrightarrow NaOH + HOCl \leftrightarrow Na^{+}+OH^{-}+H^{+}+OCl^{-}$$

NaOCl acts as a solvent for organic and fat degrading fatty acids and converts them into fatty acid salts (soap) and glycerol (alcohol), thereby reducing the surface tension of the residual solution (saponification reaction). NaOCl neutralises amino acids forming water and salt (neutralisation reaction). With the formation of hydroxyl ions, a decrease in pH occurs. When chlorine dissolves in water and it is in contact with organic matter, it forms hypochlorous acid. It is a weak acid with the chemical formula HClO and it is an oxidizer. When in contact with organic tissue HClO acts as a solvent and releases chlorine that, combined with the protein amino group, releases chloramines (chloramination reaction) that influence in cell metabolism (Estrela & et al., 2002; McKenna & Davies, 1988). HOCl and hypochlorite ions (OCl) lead to amino acid degradation and hydrolysis. Chlorine (a strong oxidant) leads to irreversible oxidation of sulfidril groups (SH groups) of essential bacterial enzymes and shows antimicrobial effect by inhibiting bacterial enzymes. This enzyme inactivation can be observed in the reaction of chlorine with amino groups (NH2) and an irreversible oxidation of sulfhydryl groups (SH) of bacterial enzymes (cystein) (Estrela & et al., 2002). Considering the physico-chemical features of NaOCl when in contact with organic tissue, these reactions can be confirmed (Mohammadi, 2008).

NaOCl is a strong base (pH >11). The antimicrobial activity of NaOCl is related to its high pH (hydroxyl ion action) (Estrela & et al., 1995). The high pH of NaOCl interferes in the cytoplasmic membrane integrity with an irreversible enzymatic inhibition, biosynthetic alterations in cellular metabolism, and phospholipid degradation observed in lipidic peroxidation. The mechanism of antimicrobial action of NaOCl can be observed verifying its physico-chemical properties and its reaction with organic tissue (Estrela & et al., 2002).

Concentration of NaOCl

As an endodontic irrigant, NaOCl is used at concentrations from 0.5% to 5.25%.There have been discussions on the use of different concentrations of NaOCl as an irrigation solution in endodontic treatment (Basrani & Haapasalo, 2012). It was proven that the lower and higher concentrations are equally effective in reducing the number of bacteria in infected root canal system but the tissue-dissolving effect is directly connected to the concentration (Meiman, 1941). When using NaOCl with lower concentrations during root canal irrigation, it is recommended to use the solution in higher volumes and more frequently to compensate for the limitations of low concentrations (Siqueira & et al., 2000). It was showed that the higher concentrations of NaOCl are more toxic than lower concentrations (Spangberg & et al., 1973; Pashley & et al., 1985); on the other hand, because of the limited anatomy of the root canal system, higher concentrations have successfully been used during endodontic therapy with a low prevalence of mishaps. (Basrani & Haapasalo, 2012). The dissolution of bovine pulp tissue by 0.5, 1.0, 2.5 and 5.0% NaOCl was evaluated under different in vitro terms by Estrela & et al. (2002). According to the results of this study; the velocity of dissolution rate of bovine pulp portions was directly proportional to the concentration of NaOCl and was larger without the surfactant. It was indicated that the variation of the surface tension was directly proportional to the concentration of NaOCl from beginning to end of pulp dissolution and also, there was an increase in surface tension of the solutions containing surfactant while there was a decrease in surface tension of the solutions without surfactant. When the temperature of NaOCl was amplified, the bovine pulp tissue was more fast dissolved. The percent variation of the NaOCl, after dissolution, was contrarily proportional to the initial concentration of the solution, namely, the larger the initial concentration of the NaOCl, the less the decrease in pH. Zehnder (2002) and Haapsaalo (2005) reported that there was no difference between these lower and higher concentration solutions in terms of tissue dissolution or antibacterial activity.

Time of usage for optimal efficiency of NaOCl

There is significant diversity in the literature concerning the antibacterial effect of NaOCl. In some articles, NaOCl is reported to kill the target microorganism in seconds, even at low concentrations, although other literatures have indicated considerably longer times for the killing of the same kinds (Haapasalo & et al., 2010). NaOCl destroys the target microorganisms quickly even at low concentrations of less than 0.1% (Vianna & et al., 2004; Portenier & et al. 2005). It is essential to remember that the existence of organic matter, inflammatory exudates, tissue residues, and microbial biomass exhausts NaOCl and weakens its effect (Basrani, 2015). Thus, continuous irrigation and adequate working time are significant factors for the efficacy of NaOCl (Haapasalo & et al., 2010).The chlorine ion, which provides the dissolving and antibacterial ability of NaOCl, is unstable and consumed quickly during the first phase of tissue dissolution, likely within 2 min (Moorer & Wesselink, 1982) which provides another reason forcontinuous irrigation (Basrani & Haapasalo, 2012).

Storage conditions of NaOCl

The stability of NaOCl solutions is reduced by lower pH, existence of metallic ions, exposure to light, open containers and higher temperatures. For long shelf-life of NaOCl, it should be keeped in light-proof (opaque glass or polythene), sealed containers, in a cool location. Recurrent opening of a container or failure to close it safely would have an effect like to leaving a container open, and the shelf life would thus be similarly decreased. If the solution is to be diluted, it should be diluted immediately after purchase, because the diluted solutions tend to deteriorate more slowly than concentrated solutions. Metallic containers should never be used because NaOCl will react with the metal in the containers. The corrosive character of NaOCl must be taken into account. As drainage pipes from sinks and dental units may utilize stainless-steel, copper, galvanized steel, PVC, polythene, or maybe other materials, plenty volume of water should be flushed down all drains to avoid the risk of perforation of drainage traps by undiluted NaOCl (Clarkson & Moule 1998).

Increasing the efficiency of NaOCl

The tissue dissolution capacity of NaOCl is related to frequency of agitation, quantity of organic material in correlation to quantitiy of irrigant in the system and surface region of tissue that was available (Moorer & Wesselink, 2003). Potential ways to develop the effectiveness of NaOCl preparations in tissue dissolution are to rise the pH or temperature of the solutions, use ultrasonic activation, or enlarge the working time (Cheung & Stock 1993).

The volume of NaOCl is more important for disinfection than its concentration. Continuous irrigation of NaOCl is essential for better tissue-dissolving capacity during root canal treatment and the use of large amount of irrigation solution compensates for the low concentration (Basrani, 2015). The volume of irrigation solution is also clinically important, because an increase in volume associates with decrease of intraradicular microorganisms and advanced canal cleaning (Baker & et al., 1975; Sedgley & et al., 2004). Using time of NaOCl is important for contact time and antimicrobial efficiency. This is particularly significant in necrotic cases where NaOCl used for 40 minutes was found to be efficient (Spangberg & et al., 1973). Higher concentration of NaOCl is provided faster dissolution of tissue. Altogether, NaOCl is a powerful proteolytic agent, which shows the best tissue dissolving capability as an endodontic irrigation solution (Clarkson & et al., 2006). In addition, in vivo the existence of organic matter (inflammatory exudate, tissue residues, microbial biomass) consumes NaOCl and weakens its action. Therefore, continuing irrigation and time are significant factors for the efficacy of NaOCl.

Another approach to develop the efficacy of NaOCl as an irrigation solution could be to rise the temperature of low-concentration NaOCl thereby increasing immediate tissue dissolution capability (Zehnder, 2006). Once heated but not used, NaOCl must be discarded immediately, because its efficacy is extinct (Cunningham & Joseph, 1980a). Additionally, heated NaOCl remove organic debris from dentin shavings more efficiently than unheated solution (Kamburis & et al., 1980). The antimicrobial features of heated NaOCl solutions have also been discussed. Moreover, with similar short-term effect in the immediate environment such as root canal system, the systemic toxicity of pre-heated NaOCl should be lower than the one of the more concentrated non-heated solution as temperature stability is achieved relatively rapidly (Cunningham & Balekjian, 1980b). Several studies showed that increasing the temperature of the NaOCl may have some advantage in killing bacteria more rapidly (Cunningham & Joseph, 1980a; Berutti & et al., 1997).On the other hand, increasing the NaOCl temperature to 37 C° does not help dissolving tissues more effectively. Although increasing the temperature of irrigation solutions is a way to kill bacteria more effectively, the temperature should not be increased more than a few degrees above body temperature as this may have detrimental impacts on the cells of the periodontal ligament (Cisneros-Cabello & Segura-Egea, 2005).

Physical agitation rises the temperature of the fluids, which in order improves their chemical activities and also increases the contact between the fluids and the root canal walls. Various devices for heating the NaOCl solution have come onto the market, however the best technique of heating NaOCl is to use an ultrasonic device (Basrani & Haapasalo, 2012). A previous study was evaluated the impacts of concentration, temperature, and agitation on the tissue dissolving ability of NaOCl and showed that tissue dissolving ability improved almost linearly with the concentration of NaOCl. The effect of agitation on tissue dissolving ability was more efficient than temperature (Stojicic & et al., 2010). The effect of mechanical agitation of NaOCl on tissue dissolution was very significant and it had great effect by severe fluid flow and shearing forces caused by ultrasound on the capacity of NaOCl on dissolving tissue(Moorer & Wesselink, 1982). For the irrigation needles to reach the more apical parts of the canal, shaping of the root canal should be at least #25 at the apex. The irrigation solution does not act apically more than 1 mm beyond the irrigation tip, therefore deep placement with small-gauge needles increases irrigation effect (Abou-Rass & Piccinino, 1982). During root canal irrigation, the needle is moved up and down frequently to agitate the solution and prevent binding or wedging of the needle. Apical negative pressure irrigation develops the irrigation dynamics and increase interaction between NaOCl and the root canal wall in the apical portion of the canal. Laser-assisted root canal disinfection seems to have the potential to develop fluid dynamics within the root canal (Pişkin & Türkün, 1995).

Using a normal syringe for the irrigation of the root canal system is the most common and easiest way in the clinical application. In the meantime, it faces a number of problems such as the vapor lock effect and a lower degree of disinfection during irrigation, if compared to its mechanical activation using shaping files or rising its temperature. The vapor lock effect is the formation of gas bubbles inside the root canal, particularly in the apical third, caused by the digestion of organic residuals by the NaOCl, decrease the diffusion of irrigation solutions and so blocking their interaction with the canal walls and inhibiting their antimicrobial and digestive activities. Mechanical activation of the irrigation solutions can decrease this effect (Agarwal & et al., 2017). Using shaping files or increasing temperature of irrigation solutions result having a lower effect in the vapor lock removal, particularly if compared to the activation of irrigation solutions using sonic/ultrasonic instruments or even to the adoption of a negative-pressure gradient. Between these methods, there are many pros and cons about distinct properties such as reaction ratio, shears stress, apical extrusion of the solution, modification of the root canal anatomy, and cost. Using photoactivation techniques, such as laser-activated irrigation (LAI) and photon-induced photoacoustic streaming (PIPS), can improve the reaction ratio of the irrigation solutions, but their cost is quite high (Dioguardi & et al., 2018).

Actually, NaOCl should be allowed to move at least 30 min inside the canal to achieve a complete disinfection of the root canal system. Because, it has been stated that the treatment result decreases when the NaOCl is used for a shorter period of time(Dioguardi & et al., 2018).

Effect of NaOCl on endodontic instruments

Nickel-titanium instruments come into contact with NaOCl when the solution is present in the pulp chamber and root canal during instrumentation. NaOCl is corrosive to metals involving selective removal of nickel and it creates micropitting from the surface. These microstructural defects can weaken the structure of the instrument, leading to areas of stress concentration and crack formation (Sarkar & et al.,1983). Previous study was showed that galvanic corrosion may occur when the nickel-titanium rotary instruments manipulate immersed in a NaOCl stored in the pulp chambers of teeth restored with metals or alloys having distinct electrochemical nobility values (Berutti & Marini, 1996).This situation may lead to pitting and cracks that change the integrity of the instrument surface, reducing its fracture resistance due to cyclic fatigue (Mohammadi, 2008).However, some researchs described that the mechanical features and cutting efficiency of Ni-Ti instrumentswere not affected by NaOCl and there were no adverse effects in short contact periods when an instrument operated in a root canal filled with NaOCl (Haïkel & et al., 1998a; Haïkel & et al., 1998b).

Canals should always be filled with NaOCl therefore, the contact time of the instruments and NaOCl would increase.

Futhermore, cutting efficiency of hand instruments improved (Russell & Rogers, 1999) and the torsional charge on rotary Ni-Ti insruments decreased (Peters & et al., 2005) in fluid-filled environments compared to dry conditions. However, corrosion of instruments in long-term contact with NaOCl is an issue to be considered. (Kuphasuk & et al., 2001). O'Hoy & et al. (2003) showed that corrosion occured when instruments were submerged in NaOCl solution for hours. It was shown that using NaOCl as an irrigating solution in root canals during several minutes as in clinical application did not change the surface structure of the instruments because of corrosion and did not cause any risk of fracture of Ni-Ti instruments (Jena & et al., 2015).

Safety of NaOCl

During the use of NaOCl as a root canal irrigation agent, several accidents such as harm to the patient's dress, splashing the irrigation solutions into the patient's or operator's eye, overflow of irrigation solutions from the apical foramen, allergic reactions to the irrigation solutions, accidental use of an irrigation solutions as an anesthetic solution have been shown in the dental literature (Hülsmann & et al., 2007).

A wide apical foramen, resorption, lateral perforation and absence of apical narrowing can cause to the extrusion of NaOCl. Additionally, most of complications happen because of wrong working length, or binding of the irrigating needle tip with no release for the irrigation solution to leave the root canal coronally (Kleier & et al., 2008). In order to avoid complications, various precautions should be taken such as awareness of the deep of needle positioning, needle tip design, avoidance of binding of the needle into the root canal, avoidance of extreme pressure during root canal irrigation to decrease the probability of NaOCl accidents. Particularly, in cases with a wide apex, the needle should be positioned some distance from the apical foramen. Additionally, during the use of NaOCl; wearing plastic bib to maintain patient's dress, providing of protective eye-wear for both the patient and the operator, the use of a leakproof rubber dam for isolation of the tooth under treatment are also protective measures (Spencer & et al., 2007).

Effect of NaOCl on the composition and structure of dentin

Dentin is formed a hydrated organic matrix which is mainly type 1 collagen, which contains 22% by weight of the material, into which is embedded an inorganic phase of carbonated apatite that subscribes noticeably to the mechanical features of dentin (Haapasalo & et al., 2014). NaOCl solutions may affect dentin properties by removing carbonate ions from dentin (Witherspoon & Ham, 2001). Dentin is degenerated by NaOCl due to dissolution of dentinal collagen (Ishizuka & et al., 2001).

The literature shows that the higher the concentration of NaOCl, the greater the detrimentals impacts on dentin. Long-term exposure to high concentrations of NaOCl has the adverse effects on the strength and physical features of dentin such as flexural strength, elastic modulus (Basrani & Haapasalo, 2012; Siqueira & et al., 2000). Zhang & et al. (2010) compared the efficacy of initial irrigation with 5.25% and 1.3% NaOCl on the erosion of instrumented radicular dentin and indicated that 5.25% NaOCl procured more dissolution of subsurface collagen. In addition, 5.25% NaOCl can have a destructive efficacy on dentin elasticity and flexural strength and therefore it may increase the risk of vertical root fracture because of the proteolytic efficacy of concentrated NaOCl on the collagen composition of dentin in some cases (Haapasalo & et al., 2010).

When NaOCl is used as the first irrigant, the effect of the NaOCl on dentin is limited because of the hydroxyapatite layer which seems to maintain the collagen fibers on the collagen. However, when using decalcifying solution (such as EDTA or citric acid), the hydroxyapatite dissolves quickly near to the main root canal, exposing the underlying collagen fibers. If NaOCl is used again at this phase, it can straight attack the protein and in a relatively short time provoke greatly destruction of the collagen backbone of surface dentin (Haapasalo & et al., 2012).

One of the major drawbacks of NaOCl is the high surface tension, which affects the tubular penetration and thus antibacterial ability of NaOCl. Zou & et al. (2010) showed that temperature, time, and concentration all played a role in determining the depthof NaOCl penetration into the dentinal tubules. Within their experimental setup, the maximum depth of NaOCl penetration into the dentinal tubules is reported to be 300 µm. According to the results, all three variables had an effect on the penetration of NaOCl, but the effect was not very marked for any factor alone.

Effect of NaOCl on bonding to dentin

The materials used during endodontic treatment can change the dentin composition and affect the interaction between the dentin surface with restorative materials due to the chemicals it contains. Controversial results on the effect of NaOCl on resin bonding have been reported. Previously studies show that the effect of NaOCl on dentin bonding is variable. This is because of variation in bonding systems' chemistries connected to the capability of their etchants to remove the degenerated dentin, occured by acid etching, as well as the remaining NaOCl, that would interfere with the free radical polymerization reaction of resin containing materials (Abuhaimed & Abou Neel, 2017).

Previously studies show that the increment in the NaOCl practice time leads to a gradual reduce in shear bond strengths for dentin adhesives (Ishizuka & et al., 2001; Nikaido & et al., 1999; Perdigao & et al., 2000). Frankenberger & et al. (2000) found that dentin bond strength and marginal adaptation decreased significantly with additional NaOCl treatment after the etching process. Remaining NaOCl may affect the polymerization of bonding resin because of the presence of oxygen. The application of neutralizing agents such as ascorbic acid or a sodium thiosulfate solution after NaOCl treatment may improve bond strength (Mohammadi & et al. 2017). There are also studies showed that NaOCl enhanced the bond strength depending on the using adhesive system (Ari & et al. 2003; Shinohara & et al., 2004; Wachlarowicz & et al., 2007). On the other hand, Correr & et al. (2004) founded that NaOCl did not affect the bond strength. These contradictory results may be related to diversity in the application of NaOCl or bonding systems.

Mechanic effect of NaOCl on smear layer

Smear layer consists of organic and inorganic components such as vital or necrotic pulp tissue, microorganisms, saliva, blood cells, and tooth structure (Diogo & et al., 2015).The smear layer formed after root canal instrumentation decreases effects of irrigation solutions and temporary dressings used for disinfecting dentinal tubules. Although NaOCl is the only irrigation solution that can dissolve necrotic and vital pulp remains, as well as the dentinal collagen, but NaOCl cannot dissolve inorganic dentin particles andcompletely remove smear layer in the root canals. Therefore, using demineralizing agents such as EDTA and citric acid have been recommended as adjuvants in root canal treatment (Zehnder & et al., 2006).

During root canal preparation, canals should be irrigated using a copious amount of NaOCl between the instruments. After the shaping process is finished, canals can be thoroughly rinsed with EDTA or citric acid. As a result of irrigation of the root canals with EDTA solution following the use of NaOCl; it has been reported that the root canal walls are cleaned well, the smear layer is removed and the dentinal tubules are clearly visible (Cergneux & et al. 1987; Goldman & et al., 1981; Calt & et al., 2000; Di Lenarda & et al., 2000; O'Connell & et al., 2000).

Effect of NaOCl on biofilm

Naturally, bacteria are able to survive either as independent free-floating cells (planktonic state) or be members of colonized surface-attached microbial communities known as biofilms. The organisms in biofilms growing in a competitive environment usually have a low metabolic rate and tend to be highly resistant to antimicrobial agents. Antimicrobial agents that easily kill free-floating organisms have not achieved the similar efficacy on the same organisms connecting on a biofilm. The structure of the biofilm also provides protection to established bacteria from immune defenses. (Iandolo & et al., 2019).

The complicated and unpredictable structure of the root canal anatomy and a wide variety of biofilms increase the difficulty in eliminating microbial biomasses from there (Alves & et al., 2011; Susin & et al. 2010). Microbial biofilms in the root canal have a very high resistance against disinfecting substances used in endodontic treatment. It has been shown that bacteria in biofilms are more resistant to influences of frequently used antimicrobial substances than their planktonic equivalents and have several mechanisms which allow them to adapt to the environment (Qiang & et al., 2008; Chavez de Paz & et al., 2007).

No known solution has all the features of the ideal irrigation solution yet. NaOCl is still the most preferred irrigation solution, thanks to its numerous benefits. It is a perfect antibacterial agent that able to dissolve necrotic tissue, vital pulp tissue, the organic components of dentin and biofilm; besides, it also has a long shelf life, and it is cheap and easily accessible (Torabinejad &Walton, 2009; Poggio & et al. 2010).Despite its superior antimicrobial properties, NaOCl can not eradicate biofilm volume totally and achieve complete killing of bacteria (Ricucci & Siqueira, 2010). The efficiency of NaOCl may be developed by raising the temperature of solution, using of agitation/activation procedures, increasing the volume of the irrigant, and reduction the pH of the irrigation solution (Neelakantan & et al., 2017).

In their study on the effect of NaOCl on biofilms, Clegg & et al. (2006) reported that the only agent providing both physical removal of artificial biofilm and killing of bacteria is 6% NaOCl. As the NaOCl concentration decreases, the number of survived bacteria increases. It is stated that the existence of biofilm and organic material decreases NaOCl activity. Nevertheless, the lower NaOCl concentrations may have been more efficient against bacteria if they were replenished or given extra time to show their antimicrobial features (Basrani & Haapasalo, 2012). Accordingly, constant renewal of NaOCl and using higher concentrations of NaOCl appear to have more efficacy on the biofilm; but, this may expose the patient to more side effects (Bosch-Aranda & et al., 2012; de Sermeño & et al., 2009).

Interaction with other irrigants

Although NaOCl has been used in endodontics as the most common irrigation solution, it has some disadvantages. These disadvantages of NaOCl are its inability for smear layer removal, the lack of substantivity and highly cytotoxic to the periapical tissues. For this reason, it is recommended to use of NaOCl in combination with adjunctive to increase its effect.

Adjunctive use of chelating agents such as EDTA or citric acid have been recommended in order to remove the smear layer formed after root canal preparation (Mohammadi & et al., 2015). Using NaOCl and EDTA together reduces rapidly and dramatically the quantity of existing chlorine derived from NaOCl, rendering the NaOCl ineffective on bacteria and necrotic tissue. To maintain the chelating capability of EDTA and disinfecting potential of NaOCl, these irrigation solutions, should not be mixed or touched each other in root canals (Zehnder & et al., 2005; Grawehr & et al., 2003). It is advised that NaOCl irrigation should be used during root canal preperation, without alternating it with EDTA. Once canal shaping is completed, canals can be completely rinsed with EDTA to remove the smear layer. After this process, a final NaOCl rinse should be applied to support debris elimination (Niu &et al., 2002).

Chlorhexidine (CHX) has an affinity to dental hard tissues (Rölla & et al., 1970), and once bound to tooth surface, it shows a long-term antimicrobial effect, which is called substantivity (Rölla & et al., 1971; Parsons & et al., 1980). Substantive antimicrobial agents are bonded to hydroxyapatite containing tissues such as dentin and are released gradually. Effectiveness of CHX in the chemical control of dental biofilm in patients with periodontal disease has already been proved (Addy & Moran, 1997; Gottumukkala & et al., 2014; Manthena & et al., 2015). Although it has very useful properties as a final irrigant, CHX cannot be considered the main irrigation solution in standard root canal treatment. Because, CHX is not adequate to dissolve necrotic tissue residues and is less effective on gram-negative bacteria than gram-positive bacteria (Naenni & et al., 2004; Hennessey,1973). It has been recommended to use NaOCl and CHX together in order to improve their antibacterial effects (Mohammadi & Abbott, 2009). CHX has been proposed to use in the root canals as the final rinsing solution after NaOCl irrigation to obtain more bacterial death than compared to using NaOCl alone (Haapasalo & et al., 2010). When solutions of CHX and NaOCl come into contact, an orange-brown precipitate called parachloroanalin (PCA) is formed (Basrani & et al., 2007; Krishnamurthy&Sudhakaran, 2010). Moreover, this precipitateseems to be mutagenicandcytotoxic and may change the tooth color. There are some concerns regarding the possible carcinogenicity (Rossi-Fedele & et al., 2012). If NaOCl is still existing in the canals and then CHX is used, a precipitate in the form of brownish-reddish mass will create, therefore the root canals should be dried using sterile paper points before the final rinse by CHX (Zehnder, 2006). It is also recommended to wash the residual NaOCl with alcohol or EDTA before using CHX to decrease PCA formation (Krishnamurthy & Sudhakaran, 2010).

Complications of using NaOCl

NaOCl solution is a very strong oxidizer that produces a corrosive reaction; therefore, it is very important for a clinician to identify the influencing factors and prevent NaOCl accident with its serious consequences including life threatening situations and potential medico-legal issues (Vivekananda Pai, 2023). In addition to its tendency to bleach clothes, it has a bad taste and possesses irritant effects on the surrounding tissue, especially at high concentrations (Haapasalo & et al., 2010; Hülsmann & Hahn, 2000; Luddin & Ahmed, 2013). When using manual irrigation, it should be ensured that the irrigation needle and syringe are securely fixated and will not separate over clothes to prevent leakage during transport or irrigation (Mohammadi, 2008).

When NaOCl contact with the patient's or operator's eyes; epithelial cells in the outer layer of the cornea can be damaged. In this case, dentists should urgently perform ocular irrigation with large amounts of sterile saline and refer the patient to an ophthalmologist for further examination and treatment (Ingram, 1990). NaOCl extrusion that occurs during root canal treatment is often called "the hypochlorite accident"; it reasons acute and sudden symptoms as well as potentially serious sequelae (Farook & et al., 2014). Kleier & et al. (2008) stated that almost half of the endodontists who responded to working (42%) in the United States had experienced at least one NaOCl accident during their practice career.

The toxic effects of NaOCl are mainly caused by its chemical composition, but other factors such as the concentration, volume, and pressure of the extruded NaOCl may also worsen the outcomes of these accidents (Mehdipour & et al., 2007). It is stated that the symptoms that occur after NaOCl extrusion are acute and sudden onset.Apical extrusion of NaOCl clinically usually begins with acute pain, swelling and redness; it then follows a typical pattern that continues with bruising and increased swelling depending on the site of NaOCl injection.This may be followed by complications such as secondary infection, sinusitis, cellulitis, and numbness or weakness of the facial nevre (Hülsmann & Hahn, 2000; Tasdemir & et al., 2008).

If NaOCl reaches the periapical area and contacts with vital tissues, the toxic effects of NaOCl on vital tissues include hemolysis and epithelia ulceration, prevention of neutrophil migration, demolition of endothelial and fibroblast cells, necrosis (Pashley & et al., 1985; Hülsmann & et al., 2007).

It is essential to reducing bleeding, controlling pain, and preventing secondary infection in the clinically management of NaOCl extrusion. When this complication occurs, immediate irrigation with saline or sterile water and additional local anaesthetic help to reducing tissue damage and pain. It is recommended to apply a cold compress to the affected area for the first 6 hours to relieve disturbance and decrease edema. Following about 6 h, cold packs need to be changed with warm compresses for the next few days. Since the potency for spread of infection is concerned to tissue destruction, medications such as antibiotics, analgesics, steroid or antihistamines should be prescribed as needed. Antibiotics may be necessary to prevent secondary infection, but there is no consensus on the routine use of antibiotics. Antibiotics should be prescribed only in cases where there is a clinical sign of wound infection or necrosis. Steroid may be used to minimize edema (Motta & et al., 2009; Hülsmann & et al., 2000).

Conclusion

Irrigation plays an essential role in successful endodontic treatment. Because of its perfect antimicrobial efficiency and tissue solubility, NaOCl is the most widely used irrigation solution in root canal treatment. NaOCl lubricates the root canals and it acts effective fairly quickly. As an irrigation solution in endodontic treatment, NaOCl is used in concentrations ranging from 0.5 to 5.25%. Overall, if lower concentration of NaOCl will be used during root canal irrigation, it is recommended that the irrigation solution shpuld be used in more volume and frequent intervals. Increasing the temperature, making activation and extending working time increase the effect of NaOCl. It should be noted that long-term exposure to high concentrations of NaOCl may have the adverse effects on the strength and physical properties of dentin. It is recommended to use NaOCl with EDTA or CA to remove the smear layer associated with mechanical instrumentation. Using the combination of NaOCl and CHX is recommended because it increases antibacterial activity and substantivity. Dentists should be careful to prevent possible NaOCl accidents during endodontic treatment.

Table 1. Properties of root canal irrigation solution (Glossary of Endodontics Terms, 2016)

A broad antimicrobial spectrum
Biocompatibility
Stability
Long antimicrobial effect
Activity in the presence of organic tissue
Low surface tension
Not to cause discoloration in the tooth structure
Removing the smear layer completely
Non-antigenic, non-toxic and non-carcinogenic
No adverse effects on the physical features of exposed dentin
No adverse effects on the sealing features of filling materials
Easy application
Being cheap

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Dental Implant Protocols in Bone Deficiency

Özge ÖZDAL ZİNCİR

Introduction

The main purpose of implant surgery in dentistry is to rehabilitate the loss of alveolar bone support in individuals. For this purpose, many implants have been produced that can be indicated in different situations and have different properties.

Zygomatic Implants

Zygomatic implants were first introduced into the literature by Branemark in 1997. It is defined for the purpose of prosthetic treatment of jaws with large volumes of bone loss due to reasons such as post-oncology bone resections, dental injuries and genetic morphological abnormalities. It has been proven over the years to be a valid method for jaw atrophy with high success rates (Tolman & et al, 1997).

While the maxillary bone is resorbed, its superior and dorsal movement creates a knife-edge appearance in the alveolar bone and a shorter and narrower retention area remains for the retention of the total prosthesis.

Bone loss that occurs when the maxilla is toothless is a very important factor in terms of advanced bone resorption. This decrease in bone volume may also cause implant loss in the long term. Since vertical bone loss occurs as a result of alveolar resorption after tooth extraction, the distance between the arches also increases. As the size of the maxilla in sagittal section decreases, the spatial relationship between the maxilla and the mandible also changes. As a result of this situation, pseudoprognathism occurs during prosthetic treatment and causes problems between the jaws. As the jawbone volume decreases, the change in muscle structure causes incompatibility of the prosthesis and prevents the implant from being placed in the ideal position (Balan & et al, 2017).

The decrease in the horizontal and vertical volume of the maxilla causes the soft tissues in the lower part of the face to collapse, resulting in an older appearance and an amount of bone that is unsuitable for the retention of the prosthesis.

Advanced posterior alveolar resorption with increased maxillary sinus pneumatosis often results in insufficient bone for implant anchorage (Malevez & et al, 2004). In these cases, bone augmentation is necessary in order to use a sufficient number and size of implants (Becktor & et al, 2005).

Severe atrophy seen together in the maxilla and mandible causes an inverse relationship between the two jaws and causes difficulties in the rehabilitation of the maxilla and mandible in the future. Thus, the regulation of the relationship between the jaws becomes more complex than in a single alveolar atrophy. Various methods have been used to increase the volume in the alveolar bone. Adequate reconstruction can be achieved with these methods.

When malocclusion occurs in dental patients, new orthodontic surgical techniques have been developed that allow the jaws to return to the correct skeletal position. Similar procedures, such as the maxillary Le Fort 1 osteotomy, can be applied in edentulous patients to correct mismatches between the jaws and restore the implant-supported dentition. Sinus lifting and alveolar bone grafting methods are well-known techniques in oral surgery. Bone grafting procedures are often used to increase bone volume and can be performed at the same surgical stage where implants are placed. (Balan & et al, 2017; Wang & et al, 2015; Wen & et al, 2014). However, it is always difficult to achieve success in these treatments and the possibility of encountering complications is high. In many cases, a second surgery may be required. In addition, the inability to perform immediate prosthetic loading in bone grafted cases is one of the disadvantages of these methods (Balan & et al, 2017).

Performing maxillectomy for the treatment of malignant tumors often causes maxillary defects and severe oral dysfunction. In these individuals, speech, chewing disorders, and many problems in functional aesthetics may be encountered. Postoperative prosthesis is made to provide oral rehabilitation of these patients with maxillary defect. However, the increase in the width of the resected area also negatively affects the stability of the prosthesis due to insufficient bone volume and loss of tooth support.

Conventional dental implants are used in the restoration of oral functions by increasing the stability and rotation of maxillary prosthetic obturators. (Malevez & et al, 2004; Becktor & et al, 2005). However, dental implant placement following resection is very difficult, as there is not enough bone support for the anchorage of the implants (Alqutaibi & Aboalreja, 2017). As an alternative procedure, the use of zygomatic implants has come to the fore to make prosthetic rehabilitation more effective. Although less morbidity is encountered with the use of zygomatic implants compared to bone grafts, immediate loading protocols can also be applied. Patient satisfaction and quality of life can be maintained at a high level by immediately performing dental prosthetic loading (Bedrossian & et al, 2006; Davo, Malevez & Rojas, 2007; Sartori & et al, 2012).

Well-indicated zygomatic implants have a high success rate (Bedrossian, 2010; Candel-Marti & et al, 2012; Goiato & et al, 2014; Almeida, Cacciacane & França, 2018).

Almeida et al., in 2018 stated that maxillary zygomatic implants are indicated for the treatment of completely edentulous maxilla with severe atrophy where no bone augmentation procedure can be applied, the treatment of severe atrophic partial edentulous maxilla to avoid sinus lift or other grafting procedures, and the treatment of maxillary reconstruction after partial or total maxillectomy.

If we list the general indications of zygomatic implants;

- Severely resorbed alveolar bone

• As a result of early tooth loss, periodontal disease, infection and trauma, the alveolar bone resorbs excessively.

• When grafting is performed, morbidity may occur in the donor area, loss of time, risk of complications and increased cost may be encountered.

- Patients with syndrome

• Posterior maxillary atrophy or multiple tooth loss occurs, as in patients with ectodermal dysplasia or cleidocranial dysplasia.

- Patients with acquired or congenital defects

• Individuals with maxillary defect following trauma or tumor resection

• Nasomaxillary reconstruction of severe oronasal relationship resulting from tumor resection

• In the prosthetic rehabilitation of patients with cleft lip and palate

• Maxillary resection

If we list the general contraindications of zygomatic implants;

- Presence of local infection or an uncontrolled systemic disease
- Availability of sufficient bone volume for conventional implants
- Having maxillary sinus pathology
- Presence of insufficient soft tissue volume around the implant area

Researchers have suggested that in individuals with atrophic maxilla, zygomatic implants can be made with 2 types of combination:

1. Combination of 2 unilateral zygomatic implants and 2 straight conventional implants

2. Placing 2 zygomatic implants in both regions

This choice should be made according to the degree of resorption in the maxillary bone. In daily clinical practice, in some cases this resorption may occur over very large areas, and in these cases implants in the anterior region may be combined with implants inclined at an angle of 30° towards the lateral paranasal bone of the pyriform aperture. These can also be combined with zygomatic implants in the posterior region. This method has not been evaluated yet (Almeida, Cacciacane & França, 2018).

Surgical protocol to be considered when performing zygomatic implants in individuals with severe maxillary atrophy:

Zygoma bone;

• It is a pyramid-shaped bone with dense cortical and partially trabecular structure.

• The zygomatic bone is 3 mm at its thinnest point and 7 mm at its thickest part.

• It has been reported that the average bone length that can be used in studies is 14 mm.

There are 3 surgical techniques:

• Branemark Technique

• Sinus Slot Technique

Positioning the implant, which is placed in accordance with the zygomatic bone contour, along the sinus through a narrow slow.

• Extrasine Technique

This method can be applied in patients with buccal concavity.

In the maxillary bone, a palatal incision is made with bilateral vertical posterior relaxing incisions. The mucoperiosteal flap is lifted and the alveolar crest, pyriform, central and posterior part of the zygomatic complex, infraorbital nerve outlet, and lateral wall of the maxillary sinus are exposed. The retractor is placed to separate the cheek and prevents the soft tissues from being damaged during drilling. Invasion into the orbit should be avoided as well as infraorbital nerve compression. After all precautions are taken, the implant areas are prepared. Corticotomy of the anterolateral wall of the maxillary sinus is performed. Drilling is done with a diamond rond drill and the sinus membrane is separated very gently.

Following the slope near the socket site, zygomatic implant beds were prepared using advanced drills under visual control, taking into account the extraoral approach and the direction of the alveolar zygomatic arch. Then, zygomatic implants are placed. By screwing the abutments, the surgical area is sutured and hemostasis is controlled.

Drugs that can be used in postoperative medication in patients with maxillary zygomatic implants:

• Moxypen (amoxicillin) 500 mg 3 times a day

• Augmentin 500/875 2 or 3 times a day

• Dalacin 300 mg 3 times a day

• Mouthwash containing 0.12% chlorhexidine

• Ibuprofen (1 time every 4 hours if needed)

• Botox (divided into 6 doses and injected into the masseter muscle on both sides from 3 points (Balan et al, 2017).

A very strict oral hygiene protocol should be applied in these patients. Patients should be called for frequent controls and the implants should be examined.

We can list the general advantages of zygomatic implants as follows:

- It does not require a second surgical field.
- Long treatment time is significantly reduced.
- It allows the total number of implants supporting the prosthesis to be less and has less cost because it does not require grafting.

Although the success of zygomatic implants has been proven by many studies, zygomatic implants also have disadvantages:

- It is a surgical procedure that is technically difficult to apply.
- There is a risk of damage to the orbit and adjacent tissues, adjacent anatomical structures such as facial nerve, infraorbital nerve.
- Sinusitis may develop after the operation.
- In case of failure or failure of primary stabilization of the implant, repositioning of the implant is very difficult.
- Surgical access to the area is difficult.
- It requires deep sedation or general anesthesia.

Complications encountered after zygoma implant treatment are mentioned in the literature:

• Sinusitis (1.8%-3%)

• Soft tissue infections (1.2-2.8%)

• Paresthesia (0.5-1.4%)

• Oroantral fistula (0.1%-0.6%) (Alqutaibi & Aboalreja, 2017).

Peri-implantitis may occur frequently in zygomatic rehabilitations (Brunelli & et al, 2012). Periodontal disease and peri-implantitis due to bacterial infections activate the cytokine cascade, causing inflammation and bone loss (Carinci & et al, 2016; Scapoli & et al, 2015; Lauritano & et al, 2016a). Oral biofilm formation (poor oral hygiene), host defense ability (smoking habit, excessive alcohol intake, genetic characteristics, previous history of periodontitis, use of bisphosphonates) may cause peri-implantitis and periodontal disease in zygomatic implants (Lauritano & et al, 2016a; Lauritano & et al, 2016b).

Zygomatic implants provide an excellent result in individuals with severe atrophic maxilla or mandible whose conventional removable prostheses cannot be tolerated. The treatment of these patients is highly satisfactory if careful case planning, meticulous surgical technique, and selection of appropriate biomaterials are followed, following a thorough preoperative evaluation.

Pterigoid Implants

Pterygoid implants were first described by Tulasne in 1992 (Tulasne, 1992).

Pterygoid implants tend to cross the maxillary tuberosity and attach to the pyramidal process of the palatal bone and then to the pterygoid process of the sphenoid bone. The long path in the pterygoid area allows the size options of pterygoid implants to be between 15-20 mm (Tulasne, 1989; Tulasne, 1992).

The pterygoid and pyramidal processes have dense cortical bone and the minimum thickness at the junction is around 6-6.7 mm (Graves, 1994; Lee, Paik & Kim, 2001). If the implant passes at a 45° angle at this junction, 8–9 mm of dense cortical bone joins, and the apex of the implant protrudes 2 mm into the pterygoid fossa (Graves, 1994).

The advantages of pterygoid implants can be listed as follows:

- It is ensured that the implant reaches the dense cortical bone (Graves, 1994; Tulasne 1989; Tulasne, 1992; Balshi, Wolfinger & Balshi, 1999).

- It is beneficial to avoid the need for sinus lift or bone grafting procedures and prevents complications related to these methods.
- It shortens the treatment time.
- Allows immediate loading of the implant.
- Eliminates the need for distal cantilevers by allowing sufficient posterior extension prosthetically.

The disadvantages of pterygoid implants can be listed as follows:

- Difficulty learning the direction in which the implant will be placed
- The precision of the technique associated with the procedure
- Difficulty reaching clinicians and patients (Balshi, Wolfinger & Balshi, 1999; Tulasne, 1989; Tulasne, 1992)
- Difficulty in assessing marginal bone loss on radiography due to the position of the implants (Balshi, Lee & Hernandez, 1995)

Complications that may be encountered with pterygoid implants:

- Severe bleeding due to palatal artery injury
- Prosthetic complications due to the presence of thin mucosa

Pterygoid implants are placed according to the anatomical structure of the person. No consensus has been established regarding an ideal position for placement of this type of implant.

Surgical Protocol for Pterygoid Implants:

Under local anesthesia, the full-thickness flap is lifted and the implants are placed between the wings of the pterygoid process of the sphenoid bone. The slot where the implant will be placed is created by using surgical drills sequentially. When placing implants in the pterygomaxillary area, they should be oriented at an angle of 45°-60° with respect to the maxillary plane. The implant should be oriented posteriorly obliquely and mesio-cranially towards the pyramidal process. While the implant angle in the anteroposterior axis is 70°-77° on average, this angle should be between 79°-84° in the buccopalatal axis.

Reducing the soft tissue thickness after the implant is placed may be beneficial in reducing the pocket depth that may occur in the future (Rodriguez & et al, 2012).

When the literature on pterygoid implants is examined, the terminology is somewhat complex depending on the area in which it is placed.

The terms “Pterygoid implants”, “Pterygomaxillary implants” and “Tuber implants” are used interchangeably.

Pterygoid Implant: Defined by Glossary of Oral and Maxillofacial Implants (GOMI) as implants inserted into the pterygoid plate towards the maxillary tuberosity (Laney, 2007).

Pterygomaxillary Implant: It is defined as implants placed in the area containing the maxillary tuber, the pyramidal process of the palatal bone and the pterygoid plate (Park & Cho, 2010; Reiser, 1998).

Tuber Implant: Defined as implants placed in the most distal part of the maxillary alveolar process. (Laney, 2007).

Few studies have measured crestal bone loss around pterygoid implants. Because of the position of these implants, it is very difficult to measure the radiographic bone level. In studies, it was reported that bone loss was similar to other maxillary implants and less than 2 mm of bone loss was encountered (Ridell, Grondahl & Sennerby, 2009). While Park and Cho encountered 0.9 mm of bone loss in pterygoid implants after 6 years of follow-up, Balshi et al. showed a mean bone loss of 1.2 mm at a 5-year follow-up (Park & Coa, 2010; Balshi, Lee & Hernandez 1995; Balshi, Wolfinger & Balshi 1999).

Studies evaluating the short- and long-term success of pterygoid implants in the literature were generally conducted within a 1-year period. It has been observed that pterygoid implants are 92% successful (Bidra & Huynh-Ba, 2011). Some investigators have reported success rates of 90.9% to 100% in 1-year and 12-year follow-ups of pterygoid implants. However, in some studies, the success rate was found below 90% due to the lack of osseointegration (Bahat, 1992; Khayat & Nadar, 1994; Balshi, Wolfinger & Balshi 2005a, b; Balshi, Lee & Hernandez, 1995; Balshi, Wolfinger G & Balshi, 1999; Penarrocha & et al, 2007; Ridell, Grondahl K & Sennerby 2009; Park & Coa, 2010; Graves, 1994; Krekmanov b, 2000).

Researchers reported that the failure rate of pterygoid implants in Type 4 bone was 35%, compared to 3% in Type 1, 2 and 3 bone. In conclusion, in the light of these findings, it can be said that it is very important to obtain primary stability and good anchorage in the posterior atrophic maxilla. This is closely related to bone quality and density (Jaffin & Berman, 1991; Salimov & et al, 2014).

In conclusion, pterygoid implants are very useful in that they are biomechanically stable and do not require cantilevers.

Placing implants in the pterygomaxillary region provides excellent bone support without the need for any maxillary sinus augmentation and bone grafting procedures. Pterygoid implants have a high success rate with minimal complications.

Apical Expansion Implants (Expandable Implants)

The apically expanded implant system was proposed by Lazarof (Lazarof, 1992; Lazarof, Hobo & Nowzari 1998). This system was created by Ashuckian and is patented in America. The implant consists of a system with two legs separated by the rotation of the inner screw (Ashuckian, 1953).

Recently, the use of short implants as an alternative to vertical bone augmentation in the rehabilitation of atrophic maxilla and mandible has come to the fore. The prognosis and patient satisfaction of short implants are quite high (Srinivasan & et al, 2014; Slotte & et al, 2015; Thoma & et al, 2015; Hentschel & et al, 2016). Biomechanical studies; showed that the crestal bone was stressed under axial and axial loading. Bone quality, implant design and position, characteristics of prosthetic devices and materials affect the stress distribution, while the length of the implant can be neglected. Unfortunately, implant length is critical in Type 4 bone (Pierrisnard & et al, 2003; Geng, Tan & Liu, 2001; Baggi & et al, 2008).

Petrie and Williams emphasized that increased implant diameter is more effective in stress distribution than implant length (Petrie & Williams, 2005). Möhlhenrich et al. stated that the diameter of the implant has a much more significant effect on the primary stability of the implant than its length (Möhlhenrich & et al, 2015).

It has been emphasized in detail that the primary stability of the implant is increased by many changes in the implant surface of short implants:

- In which area the implant is placed
- Shape of the implant
- Depth of the implant
- Diameter of the implant
- Implant design
- Surface topography (Silvan-Gildor & et al, 2014; Quaranta & et al, 2016)

In the study conducted by Reich et al. in 2017, the reliability of short expandable implants and their effect on primary stability were investigated. In this study, the expandable short screw implants; Intraoperative use, primary and secondary implant stability, crestal bone replacement, implant survival and implant success were evaluated. As a result of 3-year follow-up; implant success was determined as 93.3%. No significant difference was observed between primary and secondary stability in the maxilla and mandible. Compared with other prospective studies, the success rate of this system was found to be acceptable according to the researchers. Implant stability shows high initial and secondary values. This system can be used for functional rehabilitation in elderly individuals with limited vertical bone height.

Long-term crestal bone stability is also a question that needs to be answered for expandable implants. In studies that performed biomechanical finite element analysis in the early period, it has been reported that apically expanded implants reduce the stress on the crestal bone by up to 10% (Xiao & et al, 2011). In addition, apical expansion reduces tension in the bone around the implant.

Advantages of Apical Expansion:

• Increases primary stability.

• Increases bone-implant contact.

• Additional bicortical anchorage is obtained in the oro-vestibular direction.

• The tension in the bone in the implant neck area is reduced. (Pierrisnard & et al, 2003; Gehrke & et al, 2017)

Disadvantages of Apical Expansion:

• Asymmetrical expansion may occur when applied to hard bone.

• Presence of cavities in the apical region

However, no periapical inflammatory complications have been reported in studies conducted so far. Conical and parallel surfaces at the implant-abutment junction provide rotational stability and prevent microvoids and micromobility (Streckbein & et al, 2012).

Brenner et al. and Pommer et al. emphasized that the following prosthetic factors should be considered in order to prevent screw loosening, component fracture, marginal bone loss and loss of osseointegration:

• Crown/Implant ratio

• Cantilever length

• Condition of the opposing dentition

• Splinting of adjacent implants

• Occlusal surface reliefs and dimensions (Brenner, Brandt & Lauer, 2014; Pommer & et al, 2015).

Xiao et al. studied the effects of expandable implants in the sheep mandible. After computed tomography analysis, the ratio of bone volume to total bone volume and the number of trabeculae were found to be statistically significantly higher in apically expandable implants (Xiao & et al, 2013). The weak expandable fragment is advantageous when there is poor bone quality.

The expandable design has also been used in orthopedics, and its high quality and long-term effects have been proven in osteoporotic patients (Kummer, Strauss & Jaffe, 2007; Lemon & et al, 2005). It has been shown to provide reliable biomechanical support with low complication rate without increasing intraosseous pressure in osteoporotic conditions. In addition, studies have shown increased bone density around the implant and better stability compared to normal implants (Blumberg & et al, 2006).

All-on-4 Treatment Concept

Implant supported dentures are a very successful treatment method from single tooth deficiencies to whole mouth rehabilitation. According to the number of implants to be used in completely edentulous individuals, it is decided whether the restoration should be fixed or mobile (Misch, 2015a; Misch, 2015b). Other factors that enable the prosthetic rehabilitation option to be determined are; the remaining bone volume is the volume of the inter-occlusal space and the patient's request (Misch, 2015b, Emms & et al, 2007; Karl & et al, 2004; Saadat & Mosharraf, 2013).

In completely edentulous jaws, resorption at the alveolar crest increases over time. Implant-supported dentures provide higher patient satisfaction than removable dentures (Att & Stappert, 2003; Engquist & et al, 1988; The McGill consensus, 2003). It has been reported that the follow-up of immediate function protocols in the implant-supported prosthetic rehabilitation of the completely edentulous jaw is highly successful (Esposito & et al, 2009; Schnitman & et al, 1997; Balshi & Wolfinger, 1997; Randow & et al, 1999; Ericsson & et al, 2000).

In severely atrophic jaws, extensive surgical bone augmentation procedures are often used to provide adequate bone support for standard implant placement (10-12 mm length, ~3.5 mm diameter). Augmentation techniques, regardless of reconstructive procedures, carry a high risk of patient morbidity and complications (eg, infection, loss of graft material). However, the application of these techniques increases the treatment time and cost (Del Fabbro & et al, 2004). In order to avoid grafting procedures and to make the most effective use of existing bone, the use of angled implants has come to the fore. It is known that the success rate of these implants is similar to that of axially placed implants (Del Fabbro & et al, 2012). The use of angled implants as an alternative method has become a preferred method with minimum cantilever length in areas where the bone height is not sufficient and the nerve location does not allow axial implantation, ensuring maximum utilization of the existing bone (Maló, Rangert & Nobre, 2003; Maló, Rangert & Nobre, 2005; Fortin, Sullivan & Rangert, 2002). The concept of all-on-four was first defined by Malo in 2003 as “screw hybrid prostheses supported by 4 dental implants” (Maló, Rangert & Nobre, 2003). But Brånemark et al. have described similar approaches before (Branemark & et al, 1977).

All-On-4 Concept in Mandible

Loss of posterior teeth at an early age leads to loss of alveolar bone, causing the inferior alveolar nerve to come closer to the surface. This makes it difficult to implant in the posterior region. The All-on-4 implant concept was developed to avoid more complex techniques and to overcome the anatomical limitations of the mandible. The optimum number of implants has been reported as 4 to support a completely edentulous jaw. The posterior angled implants in this concept allow a maximum of 2 distal cantilevers to be placed at the prosthetic stage (Maló, Rangert & Nobre, 2003). With angled implants, it becomes easier to place implants in prosthetically desired areas and the distance between implants can be adjusted (Maló, Rangert & Nobre, 2005; Fortin, Sullivan & Rangert, 2002). In a study conducted with finite element analysis, researchers reported that angled implants were more advantageous when they compared the stress occurring in the coronal region of splinted angled implants with axial implants (Zampelis, Rangert & Heijl, 2007).

Mandible All-On-Four Surgery Protocol

After taking a detailed medical history from the patient, clinical and radiographic observations should be completed. Radiographic examination should be performed using orthopantomography (to assess bone height) and computed tomography (to evaluate bone volume and anatomical structures).

Implants in the mandible should be placed using a guide ruler prepared for edentulous jaws in accordance with the standard implant placement protocol. The point to be considered here is that more than 32 N torque is needed in the final stage when placing the implant.

Implant length can vary between 10-18 mm. Clinicians consider it appropriate to place 2 implants in the anterior region and 2 implants in the posterior region at an angle of 30-45˚. They argue that this arrangement allows good implant anchorage, short cantilever length and wide inter-implant spacing. Researchers emphasize that the exit profile of angled implants applied in the posterior region of the mandible should be adjusted to be at the level of the second premolar tooth (Maló & et al, 2011). Attention should be paid to the placement of the implant neck at the bone level. After the implant placement process is completed, the soft tissues should be re-adapted and the surgical area should be closed with sutures. Patients should be told that the surgical area should be kept cold for 48 hours and that they should be fed only soft and cold foods.

Implant Success Criteria in the All-on-4 Concept Applied in the Mandible;

(Evaluated considering Maló Klinik Lisbon success criteria.) (Maló, Rangert & Nobre, 2003)

• The implant fulfills its intended function as a support for reconstruction.

• The implant is stable when tested individually and manually.

• There are no signs of infection around the implant.

• No radiolucency is observed around the implant radiographically.

• There is a good aesthetic result.

• Implant supported fixed prosthesis provides patient comfort and allows good hygiene management.

Evaluation of Complications in Mandible All-on-4 Concept

Mechanical Complications:

Fracture or loosening of mechanical and prosthetic components (Maló & et al, 2011).

Biological Complications:

• Presence of pain

• Fistula formation

• Presence of other signs of infection

• Soft tissue inflammation

• Bone resorption

• Implant stability

The researchers evaluated 980 implants applied immediately in 245 patients and reported that they encountered 21 implant losses in 13 patients in the first 6-month follow-up, which is a high risk rate (Maló & et al, 2011). They reported that the implant-related success rate was 98.1% in 5-year controls and 94.8% in 10-year follow-ups. After the missing implants were removed, it was waited for 4 months and the solution was reached by applying the implants again with the same concept. The researchers, who encountered biological complications, removed the prosthesis at monthly check-ups and treated the infected area with non-surgical treatment (cleaning around the implant with chlorhexidine and hyaluronic acid gel), and resolved the biological complications. In addition, the use of antibiotics and anti-inflammatory drugs has been recommended in these patients. They reported that after 3 years of follow-up, biological complications were prevented and after 8 years of follow-up, they did not encounter any biological complications.

When researchers encounter mechanical complications; In case of screw loosening, he tightened the screws again and prevented this situation by providing occlusion control. They also recommend making night plates to prevent prosthetic wear in individuals with parafunctional habits.

As a result, All-on-4 implants are a preferable method because they show high long-term success rate and low marginal bone resorption in the concept of fixed prosthesis supported by 4 implants in the completely edentulous mandible.

All-on-4 Concept in the Maxilla

Evidence for immediate/early function in the completely edentulous maxilla is insufficient (Maló, Rangert & Nobre, 2003; Olsson & et al, 2003; Balshi, Wolfinger & Balshi, 2005b; Ostman, Hellman & Sennerby, 2008; Tealdo & et al, 2008; Bergkvist & et al, 2009). Due to the low bone density in the maxilla, this region is more difficult to plan than the mandible. In the total edentulous maxilla, especially in the posterior region, implant anchorage is limited due to bone resorption. Bone augmentation procedures are usually required in this area. The use of angled implants in the maxilla has come to the fore as an alternative to bone grafting methods (Maló, Rangert & Nobre, 2005; Fortin, Sullivan & Rangert, 2002; Krekmanov & et al, 2000a; Aparicio, Perales & Rangert, 2001). Angling the most distal implant helps to reduce the number of cantilevers. The corrected implant anchorage makes use of the cortical bone of the sinus wall and nasal fossa. The use of 4 implants in the maxilla has been supported by many in vivo studies. In vivo implant loading analyzes showed that; In all arch prostheses, the optimum loading distribution should be 2 posterior-2 anterior (cornerstones) and a good distribution should be provided (Duyck & et al, 2000). Biomechanical analysis; shows that the most distal and most anteriorly positioned implants share the most force in cantilever loading, regardless of the number of immediate implants (Rangert, Jemt & Jörneus, 1989; Maló & et al, 2011). For a given distance between the anterior and posterior implant, the load supported by the most loaded implant is independent of the total number of implants supporting the restoration. This theory has been supported by in vivo measurements (Duyck & et al, 2000). It has been stated that the use of angled implants versus axial implants in the distal is advantageous in order to use more cantilevers with finite element analysis to compare coronal stress when occlusal loading is applied (Zampelis, Rangert & Heijl, 2007).

All-On-Four Surgery Protocol in the Maxilla

After taking a detailed medical history from the patient, clinical and radiographic observations should be completed. Radiographic examination should be performed using orthopantomography (to assess bone height) and computed tomography (to evaluate bone volume and anatomical structures). After lifting the mucoperiosteal flap over the alveolar crest, relaxing vertical incisions are made in the buccal molar region. In order to see the clear position of the anterior sinus wall, a small window is opened on the sinus with a round drill.

Implants in the maxilla should be placed using a guide ruler prepared for edentulous jaws in accordance with the standard implant placement protocol. A guide ruler should be used to give the correct angle to the implants. This guide is placed in the 2 mm osteotomy area at the midline of the jaw and the titatnium band can be curved to follow the opposing jaw. Placement of implants is accomplished by following standard procedures. When placing the implant only, the final insertion torque should be at least 35 Ncm. The preparation is usually made with drills with 2 mm curves, progressing until the full drill length is reached. According to the bone density, 2.4/2.8 mm drills and 3.2/3.6 mm drills are followed. Only 3.8/4.2 mm drills are used in high-density bone. It is aimed that the implant neck and the bone level are the same. Bicortical anchorage is tried to be obtained as much as possible. With the inclined posterior implant placement, the neck region of the implant placed in the canine/first premolar area is ensured to be in the second premolar/first molar region, by placing it at an angle of 45° towards the anterior sinus wall. 30˚ abutments are used to correct the inclination of the implant. Posterior implants are mostly used with a diameter of 4 mm. Implants placed in the anterior region are oriented vertically based on the guide ruler used during the operation. At this stage, care should be taken that the apex of the implants in the anterior region do not come into contact with the apex region of the inclined implants, which can extend to the canine region. Anterior implants should be 3.3 mm, 3.75 mm, or 4.0 mm in diameter. These implants can be placed in the lateral or central tooth region. Reducing the cantilever length provides a greater advantage by placing angled implants in the second premolar/first molar tooth region in order to provide a wide distance between implants. After the implants are placed as desired, the wound edges are closed with sutures. The patient is recommended to use antibiotics and anti-inflammatory analgesics postoperatively (Maló & et al, 2011).

<u>Life Criteria of Implants in the All-on-4 Concept Applied in the Maxilla:</u>

Malo et al. determined the survival criteria of the implants they applied the All-on-4 concept according to the Malo Clinic survival criteria:

• It serves as a support for reconstruction.

• Stable when tested individually and manually.

• No signs of infection are observed.

• No radiolucency is seen around the implants radiographically.

• A good aesthetic was obtained as a result of prosthetic rehabilitation.

• Implant supported fixed prosthesis provides patient comfort and allows good hygiene management.

Follow-up and Monitoring of Marginal Bone Level

Patients who have applied the All-on-4 concept should be called for regular check-ups every 6 months after the surgery. Intraoral and radiographic examinations should be performed at intervals of 1,3,5 years after implant placement. The implant-abutment interface should be used as a reference for bone level measurements.

Complications

Mechanical complication parameters; It can be evaluated as a fracture or loss of mechanical or prosthetic components.

Biological complication parameters;

• Fistula formation

• Pain or infection

• Soft tissue inflammation

• Implant stability (It should be measured by manually applying horizontal force to the implants by removing the bridge prosthesis each time.)

Functional complication factors;

• Patient phonetics (Complaints are heard by the patient.)

• Cheek and lip biting

• Vertical dimension

• Ability to chew (Decision is made by listening to the patient.)

• Prosthesis retention (Patient complaints are heard.)

Aesthetic complication factors;

• Dental aesthetics (Complaints of the patient and dentist are listened.)

• Lip support (Upper lip is moved towards the base of the nose in the sagittal plane, and wrinkles are observed.)

• Soft tissue support (The image of the transition zone between natural and artificial gingiva is evaluated in maximum smile.)(Maló & et al, 2011)

Malo et al. evaluated 968 implants in the All-on-4 concept that were loaded immediately. As a result of the study, they emphasized that 19 implants were lost in the first year and this situation had a high failure rate. At the end of the 5-year follow-up, they reported the implant success as 98% and the prosthesis survival rate as 100% (Maló & et al, 2011). Malo et al. In their study, they reported that acrylic prosthesis fracture in 5 patients, abutment screw loosening in 2 patients, prosthetic screw loosening in 1 patient, wear of prosthesis and abutment screws in 1 patient, and implant infection in 1 patient. They suggested that while mechanical problems could be prevented by repairing the prosthesis and re-adjusting the occlusion, biological complications could also be treated with non-surgical treatment (removal of debris and flushing the area with chlorhexidine) (Maló & et al, 2011).

Multiple implants are generally preferred when immediate loading in the maxilla is performed (Tarnow, Emtiaz & Classi, 1997; Rocci, Martignoni & Gottlow, 2003; Olsson & et al, 2003; Fischer & Stenberg, 2004; van Steenberghe & et al, 2005). However, it has been reported that similar results were found when comparing fixed whole-mouth prostheses (supported with 4 or 6 implants) in the maxilla with delayed loading (Fortin, Sullivan & Rangert, 2002; Brånemark, Svensson & van Steenberghe, 1995). Malo et al. reported that the most effective prosthetic support is provided by angling the posterior implants in the maxilla, and the force shows a better distribution in the antero-posterior direction (Maló & et al, 2011). Patzelt et al. reviewed a total of 13 studies in their literature review and evaluated a total of 4,804 implants made in these studies. They reported 74% of implant loss in the first 12 months. They stated that the mean bone loss was 1.3±0.4 mm at the 36-month follow-up. In addition, when researchers evaluated the results of angled and axial position implants placed in the maxilla and mandible, they reported that they did not find a statistically significant difference (Patzelt & et al, 2014).

As a result, when the protocols of studies with good clinical results are evaluated, it is understood that 4 implant-supported all oral restorations are successful in total edentulism, and it is not necessary to place a large number of implants (Brånemark, Svensson & van Steenberghe, 1995, Maló, Rangert & Nobre, 2005, Cooper & et al, 2002).

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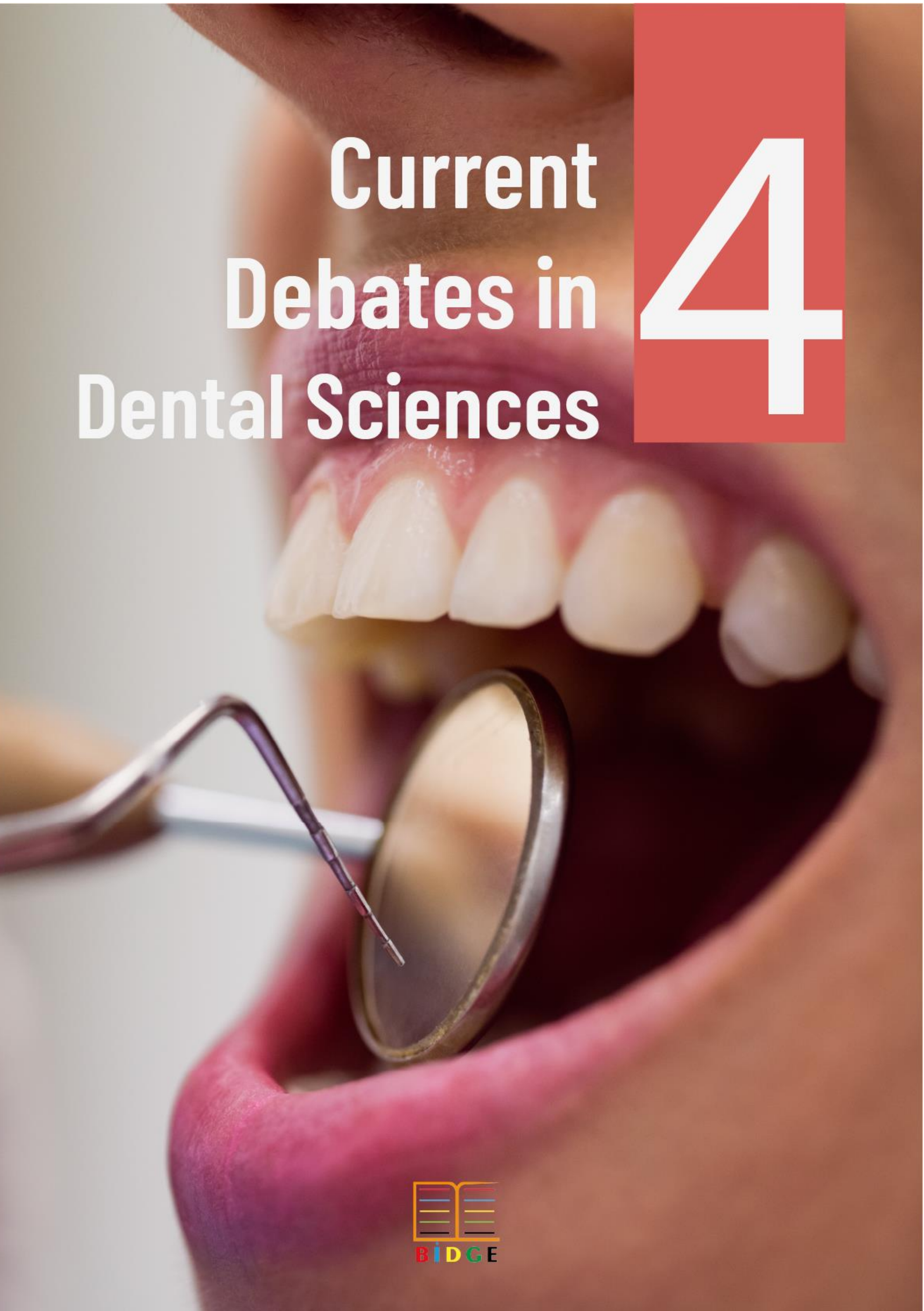

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