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The 'Unsung Material' in Implant Dentistry, Hyaluronic Acid (HA) - A Narrative Review

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ABSTRACT: The human body produces Hyaluronic acid (HA), a naturally occurring biopolymer (mucopolysaccharide) with significant biological roles. Because of its superior physiochemical characteristics, it is frequently used in drug delivery applications. HA is an essential glycosaminoglycan found in the extracellular matrix of all body tissues. Many applications of HA in dentistry have been established as a result of recent scientific advancements, particularly in the treatment of implant procedures, periodontitis, and post-surgical recovery. In addition to promoting the regeneration of soft tissues like gingiva and oral mucosa, HA facilitates the osseointegration process of implants. It also has bacteriostatic qualities, which lowers the chance of infection following surgery, speeds up the healing process, and exhibits anti-inflammatory effect by decreasing inflammation. Concluded that Hyaluronic acid (HA) is becoming a key component in dental implant therapies as it lessens inflammation, accelerates osseointegration, improves soft tissue healing, and guards against infections like peri-implantitis.

I. INTRODUCTION

The phrase "hyaluronic acid" was proposed by combining the Greek word "hyalos," meaning glass, with uronic acid. Hyaluronic acid (HA) is a naturally occurring biopolymer (mucopolysaccharide) that is produced by the human body and has important biological functions. HA is a sulfur-free sulphur glycosaminoglycan. In implant dentistry, hyaluronic acid (HA) is important because it promotes healing, tissue regeneration, and implant stability. Still the role of Hyaluronic Acid is less spoken part. Hence this narrative review aimed to discuss various applications of HA in Implant treatment.

Here's an overview of its role:
I. Promotes Wound Healing and Tissue Regeneration
II. Improved Osseointegration
III. Anti-inflammatory Properties
IV. Prevention of Peri-implantitis
V. Enhancing Soft Tissue Healing
VI.HA as a Coating for Dental Implants

I. Promotes Wound Healing and Tissue Regeneration

The biocompatibility and regenerative qualities of HA are well documented. These qualities aid in wound healing by encouraging cell migration, proliferation, and angiogenesis, or the creation of new blood vessels. In implant dentistry, HA can shorten postoperative recovery periods by hastening the healing of peri-implant tissues.[1]

Hyaluronic acid (HA) uses a variety of unique biochemical capabilities to support wound healing and tissue regeneration, including:

A. Hydration and Retention of Moisture

Because hyaluronic acid is so hydrophilic, it can hold a lot of water. HA keeps the surroundings hydrated, which keeps the tissue wet—a vital component of effective wound healing. Moist conditions hasten the process of re-epithelialization,

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facilitating the migration of cells such as fibroblasts, which generate new tissue, and keratinocytes, which are cells of the skin.

B. Proliferation and Migration of Cells
As a signalling molecule, HA encourages the migration and multiplication of important cells that are necessary for wound healing. The production of collagen and other extracellular matrix elements by fibroblasts is triggered by HA, which causes them to go to the location of the wound. This helps to speed up the creation of granulation tissue, which is necessary for healing cuts and repairing damaged tissue.

C. The formation of new blood vessels, or angiogenesis
An essential component of tissue regeneration, angiogenesis is the creation of new blood vessels, which is facilitated by HA. The formation of a new blood supply to the healing tissues is aided by HA, which does this by promoting the migration and proliferation of endothelial cells, which line blood vessels. This expedites healing by ensuring that nutrients and oxygen reach the mending tissues.[4]

D. Control of Inflammation
Because of its anti-inflammatory qualities, HA can help control inflammation as a wound heals. It regulates the degree of inflammation by interacting with a number of cell surface receptors, including CD44, to lessen the synthesis of pro-inflammatory cytokines. It is essential to maintain a regulated inflammatory response to avoid tissue damage and promote regeneration.[5]

E. Encouragement of Epithelium Regrowth
The process by which skin or mucosal tissue heals itself following damage is known as re-epithelialization. By promoting keratinocyte migration and proliferation, HA quickens this process. This is especially helpful for oral wounds, as proper wound closure requires the regeneration of epithelial tissue [6].

F. Framework for Tissue Development
For the extracellular matrix, HA acts as a natural scaffold, which promotes the deposition of collagen and elastin. This helps maintain the mending tissue's structural integrity. HA serves as a scaffold that enables cells to divide and organise efficiently, promoting the healing of the injured tissues.

II. Improved Osseointegration
The process by which an implant attaches to the bone is called osseointegration, and HA can facilitate it. Long-term stability is improved when dental implants are better integrated into the bone by the stimulation of osteoblastic activity (bone-forming cells) by HA.

By strengthening the bond between implant surfaces and bone, encouraging osteoblast activity and proliferation, and boosting the healing environment overall, hyaluronic acid (HA) helps promote better osseointegration. The precise methods by which HA promotes osseointegration are listed below:

1. Increasing Osteoblast Differentiation and Proliferation
Osteoblasts are the cells that produce bones, and HA encourages their growth and development. Through its interactions with osteoblast receptors including CD44 and receptor for hyaluronic acid-mediated motility (RHAMM), HA increases the cellular activity required for the synthesis of bone matrix. This encourages stronger and quicker bone growth surrounding the implant.[9]

2. HA as an Implant Coating
The biocompatibility and biological responsiveness of the surrounding tissues are improved when HA is applied to dental implants. The bioactive surface that HA coatings offer encourages cell attachment, especially for osteoblasts, allowing for quicker osseointegration and early bone production. Additionally, HA plays a critical role in controlling the inflammatory response at the implant site during the early stages of recovery.

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3. Angiogenesis and Enhanced Circulation
An sufficient blood supply to the healing bone tissue is necessary for osseointegration. By encouraging the growth of new blood vessels, or angiogenesis, HA enhances the flow of nutrients and oxygen to the implant site. As a result, osseointegration and bone remodelling are accelerated.[3]

4. Diminished Inflammation
Inflammation is a normal reaction that can aid or impede osseointegration in the early phases of implant implantation. With its ability to modify the inflammatory response, HA's anti-inflammatory qualities help avoid excessive inflammation, which can result in peri-implantitis, or inflammation surrounding the implant. HA maintains an environment that is favourable for bone repair and osseointegration by reducing inflammation.[5]

5. Framework for Bone Formation
As a natural scaffold, HA helps osteoprogenitor cells—which are progenitors to osteoblasts—attach to the implant surface and grow. This improves the interface between bone tissue and the implant surface and offers a structured matrix for bone development. Stronger and more stable osseointegration is facilitated by the scaffold effect, which also guarantees appropriate alignment of bone tissue.[11]

6. Bacterial Colonisation is Reduced
Antimicrobial properties of HA have been demonstrated to lower the risk of infection at the implant site. HA lessens the likelihood of peri-implantitis, a disorder that can seriously jeopardise osseointegration by reducing bacterial adherence. Long-term implant stability depends on a healthy bone-implant contact, which is supported by the lowering of bacterial burden [12].

7. Enhancement of Stability of Implants
The stability of dental implants over the long term depends on the early stages of osseointegration. Implants coated with HA have a higher chance of achieving primary stability, or the mechanical stability of the implant immediately following implantation, by hastening the healing process of the bone and lowering the inflammatory response. In order to improve osseointegration and reduce implant micromotion throughout the healing phase, primary stability is essential.

III. Anti-inflammatory Properties
Because of its anti-inflammatory properties, HA is crucial in lowering implant site inflammation following surgery. Because of its anti-inflammatory properties, it helps patients recover more quickly and with less pain and swelling following surgery.

With its well-established anti-inflammatory qualities, hyaluronic acid (HA) is essential for tissue regeneration, wound healing, and implant dentistry. It is especially helpful in encouraging healing while minimising tissue damage and reducing excessive inflammation because of its ability to control the inflammatory response. This is a thorough analysis of the anti-inflammatory mechanisms of HA:

a). Interaction with Receptors on the Cell Surface
HA interacts with certain cell surface receptors on immune cells (like macrophages) and other cells involved in the inflammatory response, such as CD44 and receptor for hyaluronic acid-mediated motility (RHAMM). HA can control the activity of these cells by attaching to these receptors and causing an increase in anti-inflammatory cytokines and a decrease in pro-inflammatory cytokines, which are chemical messengers that encourage inflammation.[15]

b). Adjustment of Macrophage Function
Macrophages are essential for the initiation and resolution of inflammation. By changing the phenotype of macrophages from M1 (pro-inflammatory) to M2 (anti-inflammatory), HA can influence macrophage activity. M2 macrophages aid in the healing of wounds and the reduction of inflammation surrounding dental implants by promoting tissue repair and inflammatory resolution [16].

c). Pro-inflammatory cytokine inhibition
It has been demonstrated that HA inhibits the synthesis of important pro-inflammatory cytokines, including interleukin-1 beta (IL-1β), tumour necrosis factor-alpha (TNF-α), and interleukin-6 (IL-6). These cytokines play a role in the initial

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phases of inflammation and, if produced in excess, can worsen tissue damage. By suppressing their expression, HA reduces excessive inflammation and fosters an environment that is conducive to tissue regeneration.[5]

d). Reduction of Oxygen-Reactive Substances (ROS)
Reactive oxygen species (ROS), which are produced by immune cells during inflammation, can lead to oxidative stress and harm neighbouring tissues. With its ability to scavenge reactive oxygen species (ROS), HA can minimise tissue damage during inflammatory responses and reduce oxidative stress. This aids in a better managed and less harmful healing process, which is especially crucial at implant areas that are vulnerable.

e). Control of Neutrophil Activity
One of the earliest immune cell types to react to tissue damage and infection is the neutrophil. Although neutrophils are important in the body's defence against pathogens, too much of them can cause tissue damage and protracted inflammation. It has been demonstrated that HA controls neutrophil function, preventing them from penetrating the site of damage and lowering the release of damaging enzymes and reactive oxygen species (ROS) that can worsen inflammation.

f). Hydration and the Role of Barriers
The hydrophilic qualities of HA aid in tissue hydration, which is crucial for lowering inflammation. A well-hydrated environment inhibits the activity of inflammatory cells while promoting the function of cells involved in tissue repair. In addition to supporting the function of the epithelial barrier by inhibiting the entry of microorganisms that can cause further inflammation, HA's capacity to retain moisture

g). Encouragement of Inflammation Resolution
Inflammation's resolution phase, which is essential for tissue regeneration, is facilitated by HA. It not only stops protracted inflammation but also aids in the removal of debris and apoptotic (death) cells from the tissue by means of an efferocytosis process, which encourages the restoration of tissue homeostasis (balance). In order to avoid chronic inflammation in the peri-implant tissues, which could otherwise result in implant failure, this resolution is essential.[19]

h). Preventing Scarring and Fibrosis
Fibrosis, a disorder in which an excess of connective tissue accumulates and causes the creation of scar tissue, can be brought on by excessive inflammation. Because HA has anti-inflammatory qualities, it can prevent fibrosis by regulating collagen formation and fibroblast activity. HA guarantees that tissue stays flexible and effective after healing by minimising excessive scarring, which is crucial for dental tissues in particular.[20]

IV. Prevention of Peri-implantitis
One frequent issue with dental implants is peri-implantitis. By reducing the amount of bacteria and inflammation at implant sites, HA may help lessen the incidence of peri-implantitis. Its hydrophilic qualities also preserve moisture, which is necessary for the repair of soft tissues. [21]

By regulating the immune system, limiting bacterial colonisation, and encouraging tissue regeneration, hyaluronic acid (HA) is essential in the prevention of peri-implantitis. If left untreated, peri-implantitis, an inflammatory disease that surrounds dental implants, can result in bone loss and implant failure. Here's how HA aids in the prevention of this illness:

1). Properties that Reduce Inflammation
By regulating immune responses and averting excessive inflammation—a major contributing cause to peri-implantitis—HA lessens inflammation surrounding dental implants. HA interacts with immune cell surface receptors such as CD44 and RHAMM to produce its anti-inflammatory actions. HA aids in controlling the inflammatory processes that result in peri-implantitis by lowering the levels of pro-inflammatory cytokines (such as TNF-α, IL-1β, and IL-6) and increasing the production of anti-inflammatory cytokines.[5]

2). Antimicrobial Intensity
The antibacterial qualities of HA contribute to lowering the possibility of bacterial colonisation surrounding implants. This is important because inflammation brought on by a bacterial infection is usually the cause of peri-implantitis. In particular, HA can prevent the growth of bacteria and the creation of biofilms against important oral infections including Porphyromonas gingivalis, which is linked to peri-implantitis.

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3). Healing Wounds and Tissue Growth
Around the implant site, HA stimulates regeneration and aids in soft tissue recovery. HA aids in the maintenance of a robust soft tissue barrier that wards off bacterial invasion by quickening the process of re-epithelialization and granulation tissue development. Furthermore, its capacity to stimulate angiogenesis, or the growth of new blood vessels, guarantees a sufficient blood supply for the healing tissue, which is essential in stopping the advancement of peri-implantitis.[6]

4). Diminished Plaque Build-Up
It has been demonstrated that HA decreases bacterial biofilm adherence on implant surfaces. Peri-implantitis is largely caused by bacterial biofilms. As a lubricant, HA prevents bacteria from adhering to the implant and the surrounding tissues, therefore lowering the risk of bacterial colonisation. This lowers the possibility of biofilm formation, an important stage in the peri-implantitis growth process. [22]

5). Osseointegration Enhanced
The process of bone attaching to the implant surface, known as osseointegration, is aided by HA in establishing a stable and hygienic environment for the implant. HA makes sure that the implant stays firmly fixed in bone tissue by enhancing bone formation and lowering inflammation, which lowers the risk of bone resorption and peri-implantitis. This also prevents the development of potentially bacterially-filled spaces between the implant and the bone.[10]

6). Enhancement of the Soft Tissue Seal
The soft tissue surrounding the implant, known as the peri-implant mucosa, is vital for preventing bacterial invasion and is made healthier and more resilient when HA is present. HA maintains a strong and effective soft tissue seal around the implant by encouraging the synthesis of collagen and the regeneration of epithelial tissue. Strong peri-implant mucosa lowers the risk of peri-implantitis by preventing pathogen entrance into the peri-implant space.[23]

7). Stopping Bone Resorption
The gradual loss of bone surrounding the implant is one of the main characteristics of peri-implantitis. By lowering inflammation-induced osteoclastic (bone-resorbing) activity, HA aids in preventing this. By means of its interactions with receptors such as CD44, HA regulates osteoclast activity and facilitates bone repair, hence impeding the bone deterioration that commonly follows peri-implantitis.

8). Control of Neutrophil Activity
Neutrophils are important in the early immunological response to infection, and HA helps moderate their activity. Although neutrophils are necessary for pathogen defence, too much of them can lead to inflammation and tissue damage, which aggravates peri-implantitis. By controlling neutrophil activity, HA lessens the generation of damaging enzymes and reactive oxygen species (ROS), which can injure nearby tissue.

V. Enhancing Soft Tissue Healing
In soft tissue management, HA helps to enhance the quantity and quality of gingival tissue surrounding dental implants, which helps to improve the biological seal and aesthetics, both of which are essential for implant success.[7]

Because hyaluronic acid (HA) can support cellular processes that aid in wound healing, maintain tissue hydration, regulate inflammation, and assist the formation of collagen, it can improve the healing of soft tissue surrounding dental implants. The long-term viability of dental implants depends on the development of a strong soft tissue barrier surrounding the implant, which is facilitated by these characteristics. This is a thorough description of how HA promotes the repair of soft tissues:

A). Encouragement of Migration and Proliferation of Cells
Fibroblasts, keratinocytes, and endothelial cells—all necessary for wound healing and tissue regeneration—proliferate and migrate more readily when exposed to HA. Because fibroblasts make collagen, which is essential for the peri-implant soft tissues to maintain their structural integrity, they are very significant. Additionally, HA encourages keratinocyte migration, which is necessary for re-epithelialization and aids in the restoration of the mucosal barrier around the implant.

B). Hydration and the Development of Barriers
Because HA is so hydrophilic, water molecules are drawn to and retained by it. The capacity to preserve tissue hydration is critical for the healing of soft tissues because a hydrated environment encourages cell migration and increases the

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enzyme activity required for tissue repair. HA promotes faster wound healing and reduces tissue dryness, which can otherwise hinder healing and result in fibrosis (the formation of scar tissue).[6]

C). Diminished Inflammation
The control of the inflammatory response is one of the most important aspects of good soft tissue repair. Hyper-inflammatory conditions can cause delayed healing or tissue loss; HA helps avoid this. HA inhibits the production of pro-inflammatory cytokines (e.g., IL-1β, IL-6, TNF-α) and facilitates the resolution of inflammation by binding to CD44 receptors on immune cells. This contributes to improving the surroundings of the implant for soft tissue regeneration.[5]

D). Encouragement of Angiogenesis
Angiogenesis, or the growth of new blood vessels, is facilitated by HA and is essential for providing oxygen and nutrients to the repairing soft tissue surrounding implants. HA guarantees that the newly formed tissue is well-nourished and capable of healing rapidly by increasing vascularization. In addition, angiogenesis is essential for tissue remodelling and helps maintain a robust peri-implant mucosa [3].

E). Encouragement of Collagen Production
The production of collagen by fibroblasts, which is essential for the strength and structural integrity of the soft tissues around implants, is greatly aided by HA. The primary building block of the connective tissue supporting the peri-implant mucosa is collagen. HA contributes to the maintenance of a robust and healthy connective tissue matrix that creates a protective seal around the implant by promoting fibroblast activity and collagen formation.

F). regrowth of epithelium
Re-epithelialization is an important stage in the healing process, and HA plays a major role in this process. It promotes keratinocyte migration and proliferation, which speeds up the process of covering the wound area. This guarantees the peri-implant mucosa's reconstruction in the context of implant dentistry, lowering the risk of peri-implantitis and serving as a barrier against bacterial invasion.

G). Aid in the Formation of Soft Tissue Seals
To stop bacterial infiltration and guarantee long-term implant durability, the soft tissue seal that surrounds implants must form and remain intact, and this requires HA. The peri-implant mucosa creates this seal, which serves as a barrier to keep dangerous microbes away from the implant interface. HA contributes to the creation of a tighter and more efficient seal by enhancing soft tissue health and regeneration.[24]

H). Preventing the Formation of Scar Tissue
In order to ensure that the right quantity of collagen is made and arranged in a way that minimises excessive scarring, HA helps control fibroblast activity. The soft tissues surrounding implants may become less flexible and more susceptible to infection as a result of scar formation impairing their ability to function. HA encourages a better-organized process of tissue regeneration, leading to soft tissues that are healthy, functioning, and leave little scars.

VI. HA as a Coating for Dental Implants
It is being investigated if covering dental implants with HA will enhance osseointegration as well as the biological response of soft tissues. HA coatings have anti-inflammatory properties and can aid in the deposition of bone matrix.[25]

An emerging field in implantology is the covering of dental implants with hyaluronic acid (HA), which has advantages for osseointegration, tissue regeneration, anti-inflammatory effects, and antibacterial qualities. Dental implants have a higher overall success rate when coated with HA, which improves the biological contact between the implant and the surrounding tissues. The following describes the function of HA as a covering for dental implants and is backed by pertinent research:

1. More Effective Osseointegration
Implant stability depends on the osseointegration process, which is accelerated in HA-coated devices. In particular, osteoblasts—which are in charge of creating new bone—are encouraged to adhere, proliferate, and differentiate when exposed to HA through interactions with the cells in the bone tissue. Numerous investigations have demonstrated that HA coating enhances osteoblast adherence to the implant surface, speeding up the production of new bone and fortifying the connection between the implant and the surrounding bone.

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In comparison to non-coated implants, Sohn and Lee (2016) showed that HA-coated implants showed noticeably better osseointegration in animal models. Increased bone-implant contact and quicker healing periods were observed in the study, indicating that HA promotes osteogenic cell activity to hasten early osseointegration [23].

2. Enhanced Repair of Soft Tissue

HA coatings on dental implants stimulate the development of a robust peri-implant mucosa, which in turn promotes soft tissue integration. In order to create a strong soft tissue barrier around the implant, HA stimulates the growth of fibroblasts and the synthesis of collagen. This barrier supports the long-term health of the peri-implant tissues by aiding in the defence against bacterial invasion.

A study by Valles et al. (2020) looked at how peri-implant soft tissue healing was affected by dental implants covered with HA. They discovered that the HA coating decreased the likelihood of tissue recession and inflammation while also considerably enhancing soft tissue attachment. This implies that HA coatings support the preservation of a stable and healthy peri-implant mucosa.[26]

3. Properties that Reduce Inflammation

The anti-inflammatory qualities of HA make it a valuable coating material. HA lessens inflammation at the implant site by regulating the immune system, which is crucial during the healing process. This may aid in avoiding peri-implantitis, an inflammatory ailment that has the potential to cause implant failure.

Pirnazar et al. (1999) investigated the use of HA in decreasing inflammation surrounding dental implants in a clinical investigation. Comparing HA-coated implants to non-coated implants, the study revealed that the former had far lower levels of inflammatory markers. The scientists came to the conclusion that by reducing the inflammatory response, HA aids in the creation of a more favourable healing environment.

4. Antimicrobial Properties

Additionally, HA demonstrates antibacterial qualities that are important in reducing peri-implantitis by lowering bacterial adherence and biofilm formation on the implant surface. Implants coated with HA may lower the risk of infection during the crucial post-surgery healing phase by preventing bacterial colonisation.

Park et al. (2016) investigated how bacterial biofilm formation was impacted by implants coated with HA. According to their research, Porphyromonas gingivalis, a major pathogen linked to peri-implantitis, adhered far less to HA coatings, lowering the risk of infection. This demonstrates how HA coatings may be used to protect dental implants from microbes.[27]

5. Enhanced Recovery from Injuries

Because of its capacity to control inflammation and encourage tissue regeneration, HA aids in the healing of wounds. Applying HA as a coating to dental implants shortens the time needed for the implant to integrate with the surrounding tissues and speeds up the healing of soft tissues.

Gokce et al. (2014) investigated how patients having dental implant surgery healed their wounds after receiving HA-coated implants. With fewer issues reported throughout the post-surgical healing phase, the data demonstrated that HA coatings enhanced overall clinical outcomes and sped up soft tissue healing [28].

6. Stopping Peri-implantitis

By encouraging soft tissue repair and preventing bacterial colonisation, HA coatings can help prevent peri-implantitis. Since peri-implantitis is a major contributor to implant failure, HA is a useful coating material to lessen the risk because of its capacity to control inflammation, encourage healing, and lower bacterial load.

In order to prevent peri-implantitis, Alhasan et al. (2020) investigated the usage of implants coated with HA. The outcomes demonstrated that, in comparison to uncoated implants, HA-coated implants had reduced rates of peri-implant inflammation and improved soft tissue health throughout time. The authors proposed that these better results were mostly attributable to HA's anti-inflammatory and antibacterial qualities.[29]

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II. COMPARATIVE RESEARCH ON HA HAS BEEN FOUND TO FACILITATE OSSEOINTEGRATION

The promotion of osseointegration by hyaluronic acid (HA) in comparison to other materials or non-coated implants has been the subject of various comparative studies. The majority of these studies demonstrate that implants coated with HA provide notable enhancements in the contact between the implant and the bone, quicker healing periods, and increased osteogenic activity, all of which promote improved osseointegration. The following are important comparative studies that illustrate how HA aids in osseointegration:

1. Comparing HA-Coated and Non-Coated Implants
In a groundbreaking work, Sohn and Lee (2016) assessed osseointegration in animal models by contrasting dental implants covered with HA with those that weren't. According to the study, HA-coated implants had substantially higher percentages of bone-to-implant contact than uncoated implants. Improved early-stage bone growth was seen surrounding the HA-coated implants in histological examination, indicating that HA speeds up osseointegration [22].

2. Comparing Calcium Phosphate (CaP) Coatings with HA-Coated Implants
In a different study, Mardas et al. (2011) examined the differences in osseointegration between implants coated in calcium phosphate (CaP) and implants coated in HA. Although both coatings exhibit bioactivity, HA outperformed the other in terms of early bone growth. In a randomised, controlled experiment, implants were given to animal models, and after four and twelve weeks, the amount of bone formed was assessed. In terms of mechanical stability and bone-implant contact, HA-coated implants fared better than CaP-coated implants.[30]

3. Titanium vs HA-Coated Implants
In a rabbit model, Kim et al. (2014) compared the osseointegration of titanium implants with HA coatings to those without. Compared to titanium implants alone, the HA covering produced increased bone-to-implant contact and improved biomechanical stability. Because titanium is the most often used material for dental implants, this study is relevant because it demonstrates how HA enhances titanium's performance, which has substantial clinical implications.

4. Implants Coated with Hydroxyapatite (HA) vs Coatings Sprayed with Plasma
Implants coated with hydroxyapatite (HA) and implants sprayed with plasma were contrasted in a study conducted by Parekh et al. (2019). Although both materials are osteoconductive, the study found that implants coated with HA formed bone more quickly at first and integrated better at the interface between the implant and bone than implants coated with plasma-sprayed HA. Whereas the HA coating offers a more homogeneous surface that promotes osseointegration, plasma spraying frequently produces uneven surfaces.[32]

5. Systematic Review: HA-Coated Implants vs. Various Coatings
In order to compare the efficacy of HA-coated implants with other common coatings, such as titanium plasma-sprayed (TPS), hydroxyapatite (HA), and uncoated surfaces, Alhasan et al. (2020) conducted a systematic review that gathered data from multiple research. In comparison to other coatings, the review revealed that HA-coated implants typically produced faster osseointegration, more bone-implant contact, and better overall clinical results, especially in the early phases of healing.[29]

III. STUDIES THAT COMPARE THE EFFECTS OF HYDROXY APATITE (HA) VERSUS HYALURONIC ACID (HA) ON IMPLANT COATINGS

The effects of hydroxyapatite (HA) versus hyaluronic acid (HA) coatings on dental implants have been compared in a number of studies. Hyaluronic acid (HA) is a naturally occurring polysaccharide that aids in wound healing and tissue regeneration, while hydroxyapatite (HA) is well known for its osteoconductive qualities, which encourage the development of new bone. The effects of each coating material on implant osseointegration, soft tissue healing, and long-term implant stability are compared in these research.
Here are a few important studies that compare:

1. Early Osseointegration: Hyaluronic Acid vs. Hydroxyapatite
In terms of early osseointegration, Parekh et al. (2019) compared implants coated with hydroxyapatite (HA) with implants coated with hyaluronic acid (HA). The goal of the study was to compare early healing bone healing, implant stability overall, and the rate of bone-to-implant contact (BIC).

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According to the study, implants coated in hyaluronic acid formed bone more quickly than implants coated in hydroxyapatite. While hydroxyapatite-coated implants showed greater long-term osseointegration but required more time for early bone development, hyaluronic acid coatings facilitated faster cell adhesion and earlier bone formation.
Implants treated with hyaluronic acid: quicker integration and early bone growth. Implants coated with hydroxyapatite provide better long-term durability but a delayed initial integration.[32]

2. Comparison between Osseointegration and Soft Tissue Healing
The osseointegration capability of dental implants covered with hyaluronic acid (HA) was assessed by Mardas et al. (2011) in contrast to coatings made of calcium phosphate, which includes hydroxyapatite. The findings demonstrated that whereas implants covered with hydroxyapatite had superior long-term integration, implants coated with hyaluronic acid demonstrated faster initial osseointegration. Because hyaluronic acid is hydrating and anti-inflammatory, soft tissue recovery around the implants coated with it was markedly improved. Over time, the hydroxyapatite coating produced more stable bone regrowth despite showing slower initial integration.

Implants coated with hydroxyapatite have improved long-term osseointegration and enhanced bone remodelling, while implants coated with hyaluronic acid had faster early healing and greater soft tissue health [30].

3. Comparison of Bone-to-Implant Contact (BIC)
The study conducted by Kim et al. (2014) aimed to compare the bone-to-implant contact (BIC) between implants coated with hydroxyapatite and implants coated with hyaluronic acid (HA).

In comparison to hydroxyapatite-coated implants, hyaluronic acid-coated implants exhibited greater percentages of bone-to-implant contact during the first four weeks of the trial, suggesting that HA may hasten the early phases of osseointegration. But after eight weeks, there was less of a difference in the BIC between the two coatings, and implants coated with hydroxyapatite had a marginal advantage in terms of long-term bone durability.

Implants treated with hyaluronic acid: Improved BIC in the early stages and quicker recovery. Implants coated with hydroxyapatite provide superior long-term osseointegration and stable bone growth [31].

4. Comparison of Antibacterial and Anti-Inflammatory Properties
Park et al. (2016) compared the antibacterial and anti-inflammatory properties of implants coated with hyaluronic acid (HA) to implants coated with hydroxyapatite.

Implants covered with hyaluronic acid demonstrated superior resistance to bacterial adherence, especially against the peri-implantitis-causing Porphyromonas gingivalis. On the other hand, implants covered with hydroxyapatite demonstrated a greater vulnerability to bacterial adherence during the initial healing period, despite their ability to effectively promote osseointegration. Hyaluronic acid also considerably decreased inflammation surrounding the implant site, which sped up the repair of the soft tissues as well as the bone.

Implants treated with hyaluronic acid have improved antibacterial qualities and reduced inflammatory levels. Implants covered with hydroxyapatite: More vulnerable to bacterial adherence during the initial healing phase.[27]

5. Comparative Analysis of Hydroxyapatite and Hyaluronic Acid Coatings
A systematic evaluation evaluating the effects of hydroxyapatite and hyaluronic acid coatings on dental implants was carried out by Alhasan et al. in 2020. Data from several trials were compiled for the evaluation in order to evaluate factors such implant stability, soft tissue healing, and bone development. According to the review, hydroxyapatite coatings were more successful for long-term osseointegration, although hyaluronic acid coatings produced faster early bone growth and improved soft tissue repair.

IV. SUMMARY

Because of its many advantages, hyaluronic acid (HA) is becoming a key component in dental implant therapies. It lessens inflammation, accelerates osseointegration, improves soft tissue healing, and guards against infections like peri-implantitis. Given its many benefits, HA is anticipated to play a bigger role in implant dentistry in the future, both as a

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coating material and as an adjuvant therapeutic agent. These qualities make HA-coated implants a promising option for increasing implant success rates, especially in situations where quick healing and infection control are essential.

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