Factors Influencing Marginal Bone Loss around Dental Implants: A Narrative Review

Jakub Kowalski [1], Barbara Lapinska [1], Joseph Nissan [2] and Monika Lukomska-Szymanska [1,*]

1   Department of General Dentistry, Medical University of Lodz, 92-213 Lodz, Poland;
    jakub.kowalski@stud.umed.lodz.pl (J.K.); barbara.lapinska@umed.lodz.pl (B.L.)
2   Department of Oral Rehabilitation, School of Dental Medicine, Tel Aviv University, Tel-Aviv 6997801, Israel;
    nissandr@post.tau.ac.il
*   Correspondence: monika.lukomska-szymanska@umed.lodz.pl; Tel.: +48-42-675-74-61

Abstract: Implant supported dental prostheses are increasingly used in dental practice. The aim of this narrative review is to present the influence of transmucosal surface of prosthetic abutment and implant on peri-implant tissue. The article describes causes of bone loss around the dental implant. Moreover, properties of different materials are compared and discussed. The advantages, disadvantages, and biomechanical concept of different implant-abutment connections are presented. The location of connections in relation to the bone level and the influence of microgap between the abutment and implant are described. Additionally, the implant abutments for cemented and screwed prosthetic restorations are compared. The influence of implant and abutment surface at the transmucosal level on peri-implant soft tissue is discussed. Finally, the biological aspect of abutment-implant connection is analyzed.

Keywords: dental implant; prosthetic abutment; microgap; implant-abutment interface; osseointegration; peri-implantitis

1. Introduction

Dental implants are widely used for oral prosthetic rehabilitation in case of partially (single or more missing teeth), as well as fully edentulous patients. It was demonstrated that osseointegrated implants have a high survival rate (cumulative mean of 94.6%, SD 5.97%) with a follow-up period of up to 20 years [1]. Among the absolute contraindications for dental implants are poor oral hygiene, drug abuse, psychiatric illness, and patients' unrealistic expectations. Whereas, circulatory system diseases, diabetes, xerostomia, endocrine, and metabolic disorders (with an adequate treatment) are generally considered as relative contraindications. In addition, relative contraindications include aged patients, as well as patients with a low quality and density of bone, with bruxism, periodontal diseases, oral carcinomas, and generally immunocompromised patients [2,3]. An individual approach to the patient allows considering the negative influence of systemic diseases on the dental implant treatment outcome [4]. The overall implant loss limited by implant region and bone quality varied from 0.3 to 3.3% [5]. In medically compromised patients, the implant failure was 0.0–22.5% [6–8]. Most of the implant failure was observed in patients with smoking history (37%), hypertension (20.8%), and diabetes (20.3%) [9].

2. Causes of Bone Loss around the Dental Implant

Factors that have an impact on bone loss around implants can be divided into local, systemic, and social. The local factors include the implant body, occlusal loading, size of implant, and biological aspects. Structure-related factors of bone loss involve the type of connection between the implant and abutment (internal hex, external hex, conical, and their modifications), as well as the size of a microgap between the implant and abutment. Moreover, the type of an implant (one-piece, two-piece, and multi-part implant), its shape

(tapered, non-tapered), diameter, length, stiffness and surface topography (created by mechanical machining, etching, oxidizing, sandblasting, laser patterning) or thread of the implant (e.g., V-thread, buttress, reverse buttress) play a key role in the process [10].

Occlusal overload applied on implant-supported prostheses may contribute to peri-implantitis and can result in implant loss [11,12]. Susceptible to overloading, cortical peri-implant areas are mostly affected by implant diameter, irrespective of bone-implant interface length [13]. However, the length as well as the implant diameter can affect bone loss around implants. Researchers examined implants with a diameter of 3.0–5.0 mm and a length of 7.0–16.0 mm. Bone loss increased with shorter and wider implants, however there were no significant differences in crestal bone loss for the tested implants regarding different diameters and lengths of implants [14–16]. On the other hand, another retrospective study mentioned the highest failure of implants with a diameter lower than 3.75 mm and longer than 11.5 mm [5]. Implants with a lower diameter placed in the posterior region may cause an excessive bone loss due to the reduced contact area between the implant and bone and subsequent poorer osseointegration. The higher the implant diameter, the higher the contact surface area that reduces stress due to overload around the implant neck. Stress values were decreased when the implant diameter increased. Moreover, when the implant length increased, better stress distribution was observed [13,17].

Biological factors that influence bone loss are peri-implantitis, poor bone quality, surgical procedure of implant placement, early loading of the implant, and poor osseointegration. Peri-implantitis manifests clinically with bleeding on probing and in radiograph as bone loss around the implant [18]. The adopted types of bone quality (according to Lekholm and Zarb [19]) assume as type 1—homogeneous, non-vascularized bone, type 2—combination of cortical bone with bone marrow cavity, type 3—mainly trabecular bone, type 4—thin cortical part and low-density trabeculae. Poor bone quality—soft and providing improper initial stabilization—leads to complications in the implant treatment. This is manifested by a frequent high loss of bone and implant [20]. It is characterized with a low density of trabecula and thin cortical bone [21]. The surgical procedure of implant placement can cause bone loss in case of placing implants in a very soft bone using methods, such as bone regeneration or condensation, improperly performed with regards to the bone condition [22]. Bone loss can be observed with the early loading of the implant due to the improper initial stabilization. The implant initial stabilization should amount up to 30–35 Nm to ensure the predictable results [23]. These biological factors also lead to poor osseointegration and implant failure. The prevention of biological factors causing bone loss relies on regular control of infection, maintaining good oral health, implant surface decontamination, correctly performed surgical procedure, and obtaining osseointegration [24]. For control of infection and maintaining good oral health, the patient is instructed to mouth rinse with 0.2% or 0.12% chlorhexidine. This procedure reduces infection by 4.6%. Implant surface decontamination should be performed to remove biofilm from the peri-implant tissue, from the pocket and implant surface [25]. To prevent an incorrectly performed surgical procedure, precise examination, X-rays, detailed planning including assessment of bone quality and quantity, should be performed. Moreover, placing the implant at a correct inclination angle, as recommended by the manufacturer's torque value and performing the treatment in aseptic conditions can prevent complications. Treatment of peri-implant disease includes non-surgical, surgical, antibiotics delivery, and tissue regeneration antimicrobial membranes around implants [26,27]. The antibiotic application significantly affects the implant treatment by reducing the early failure to 1.55% from 4.61% of patients with no antibiotics or placebo. No significant difference was observed in the decreasing failure rate applied by the pre- or postoperative antibiotics regimen [28]. The lack of osseointegration should be treated with removal of loose implant, debridement of the bone, and replacement with a new implant after healing [29].

Within other factors that can lead to bone loss, systemic factors (patient's age, general condition, and genetic predispositions), as well as social factors (patient's socioeconomic status, oral hygiene, and stimulants consumption) play an important role [22].

3. Material Properties

Currently, most dental implants are made out of titanium (Ti) and its alloys or zirconium dioxide (ZrO_2). Alternative materials used in implants are steel, cobalt chromium alloys, gold alloys, tantalum (Ta), aluminium (Al_2O_3), carbon abutment coating (DLC), and numerous polymers. As for the abutments, they are also made of titanium and its alloys or zirconium (ZrO_2), as well as surgical stainless steel, gold alloy, and polyether ether ketone (PEEK).

3.1. Titanium

Titanium is highly resistant to corrosion, light, biocompatible, and sustainable. These properties ensure stable osseointegration and good resistance to mastication forces [30]. Epithelial attachment around the titanium implant is longer with a smooth than rough surface [31]. Moreover, titanium abutment allows for obtaining similar epithelial and connective tissue attachment as the ceramic one [32]. It has been proven, that a smaller apical soft tissue movement occurs with an abutment made of titanium and zirconium compared with gold and platinum [33]. The recessions around titanium abutments of implants per year (after 1–5 years) are considerably lower compared to the ceramic ones [34].

Initially, ceramic materials were applied to cover the metal to enhance the osseointegration. Ceramic coating of implants with, e.g., bioactive ceramics, such as calcium phosphates and bioglasses, and inert ceramics, including aluminum oxide and zirconium oxide, ensures their better resistance and longer maintenance [35]. It has been proven that zirconium oxide coating (ZOC) enhances osseointegration. More evident bone growth and mature bone was seen around ZOC implants [36].

3.2. Zirconium

Zirconium implants, similarly to titanium implants, are biocompatible and radiopaque, providing excellent mechanical properties: High hardness, bending strength, and toughness [36]. There has been a marginally lower inflammation around abutments made of zirconium compared with titanium abutments. Additionally, bone loss after 12 months was smaller with zirconia abutments [37]. Zirconium oxide has a high resistance to corrosion and wear, and supreme bending strength (800–1000 MPa) in comparison to other ceramics [35]. However, a 3 to 7 times smaller microgap between the titanium implant and abutment has been observed, compared to the connection between the implant and abutment made of zirconium [38]. Furthermore, a bigger wear and deformations with titanium implant connection were observed [39].

4. Types of Implants

The implant systems can be categorized according to the number of parts of mechanical design to one-piece and two-piece implants. The one-piece and two-piece implants can be used in one-stage, as well as in two-stage treatment procedure [40]. In a one-piece implant, the endosseous and the abutment part are one unit, with prosthetic restoration placed on top of the implant. Whereas, two-piece dental implants consist of a part placed in the bone (implant) and a separate supragingival part (prosthetic abutment). Abutment (in two-piece implants) can comprise several parts (e.g., multi-unit constructions) used depending on the clinical situation. Such multi-unit abutments are indicated when the angulation correction of inadequately/disadvantageously positioned implants is needed, e.g., in case of implant-borne multi-unit or full-arch prosthetic restorations. Then, several multi-unit abutments are used to maintain the aesthetics and emergence profile in compromised cases of edentulous spaces [41].

One-piece implants are placed in one-stage surgery with immediate implant loading. The over 2-mm bone loss was observed in 6% of cases of one-piece implants, while in 16% of cases of two-pieces implants in 1-year follow-up [42]. Such advantageous results can be attributed to the absence of a microgap between the abutment and implant in one-piece implants [40]. On the contrary, over 2-mm bone loss was reported in 49% of

one-piece implants in contrast to 7.7% of two-piece implants [43]. However, the higher apical migration of soft tissues was observed for one-piece implants. The apical migration of soft tissues can adversely affect the contour and the aesthetics of soft tissues around the implant due to the lack of suitable shape and surface of a prosthetic abutment [44].

5. Location of Implant-Abutment Connection in Relation to the Bone Level

There are several implant systems categorized according to their location in relation to the bone level and the construction of the implants.

5.1. Subcrestal Implants

Implants placed below the edge of the bone are subcrestal implants. It is worth mentioning that a comparable number of inflammatory cells around the subcrestal and crestal implants was found [45]. The implant abutment connection promotes bacterial colonization, which can result in peri-implantitis [45]. Therefore, it is very important for implants at the bone or subcrestal level to transfer the prosthetic substructure as far as possible on the free gingival margin by choosing a longer prosthetic abutment. In addition, it allows for better aesthetics of the restoration. Moreover, the subcrestal position of implants diminishes the probability of exposure of implants and reduces inflammations around implants [45].

5.2. Bone-Level Implants

Another type are implants placed at the bone level. In case of bone-level implants, the transmucosal component is a separate part of the implant and is located on the buccal side of the bone. Bone-level implants are placed in such a way that the prosthetic platform of the implant is at the level of the bone. This allows for a very good emergence profile and possible soft tissue corrections. It has been proven that the smallest bone loss occurs around implants, where the microgap between the abutment and implant is placed 1–2 mm above the bone [46]. However, in this case, the rough part of the implant, which should adhere to the hard tissues, may come into contact with the soft tissues and cause inflammation. The risk arises due to the positioning of the implant above the bone. Therefore, bone-level implants without the concept of platform-switching should have approximately 1 mm of polished cervical surface, which allows for the adhesion of the soft tissue [46].

5.3. Tissue-Level Implants

In addition, there are many implant systems that are embedded at the level of soft tissues. Their growing popularity can be attributed to the fact that placing the implant at the soft tissues level causes just a slight bone loss and allows for maintaining good hygiene of the prosthetic restoration. In the tissue-level systems, the transmucosal component is the main part of the implant. It is important to position this part above the bone level since by contact with the polished surface, it causes bone loss. The biological width will thus be facing this transmucosal neck. It is supposed to be as biocompatible as the implant, which cannot become loose or be removed, and which harbors no microgap. Moreover, a lower number of bacteria is found for tissue-level or one-piece implants since there is no contaminated connection at the crestal bone level. Bacteria can have an adverse effect on the biological width or contribute to the formation of peri-implantitis and the implant failure [47]. However, there were no differences in the size of the epithelial attachment with implants at the bone and soft tissue level [48,49].

5.4. Platform-Switching Concept

Platform-switching is a concept of placing a prosthetic abutment of a diameter smaller than that of an implant [50]. It results in smaller bone loss around the implant neck and favourable stress distribution [51–53]. Platform-switching allows the correct adhesion of marginal epithelium to an implant surface and the proper profile of soft tissues [54]. It can be applied in either the external or internal implant-abutment connection [53]. This

concept applied in bone level implants causes a lower decrease of epithelial attachment in comparison to other abutments [55]. In the supracrestal implants with platform-switching, bone loss was slightly less pronounced than in the case of subcrestal implants, yet the statistical significance was not observed. Still, it is recommended to position implants on the crestal level or 1–2 mm subcrestally [56].

6. Types of Implant-Abutment Connections

There are several types of connections between an implant and a prosthetic abutment: External (external hex), internal (internal hexagon and octagon), and their modifications, e.g., conical (Morse cone), tube-in-tube [47,57] (Figure 1).
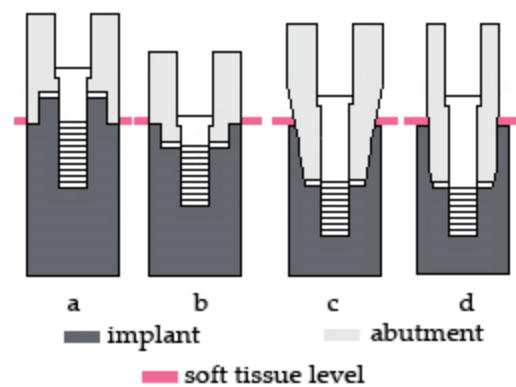

Figure 1. Types of implant-abutment connections: (**a**) External hex; (**b**) internal hex; (**c**) conical connection; (**d**) tube-in-tube connection.

6.1. External Connection

External connection, where the abutment forms the external edge of an implant, was introduced by Branemark [58]. Its distinctive feature is the shape of a hexagon or octagon (Infinity Implants, Neodent, Dentoflex, Titanium Fix, SIN, Conexao). The abutment-implant junction with an external connection is localized close to the crestal bone. Higher bone loss and increased papillary bleeding index (PBI) were observed within the external connection compared with the internal connection [59].

The external connection is most commonly made of an hex, in which the prosthetic part is located towards the outside margin of an implant construction. This causes bone loss around the implant [60]. Many modifications of an external connection with or without hex were introduced over the years. In external hex, with time, the construction loosening caused by the weakened quality of connection may occur [57]. External connections were modified to decrease the possibility of rotating the abutment, to reduce the screw loosening (during implant load), to simplify the prosthetic procedure, and to increase the abutment alignment in various vertical positions towards the implant [61].

6.2. Internal Connection

However, to reduce the bone loss, increase the implant stability, and enhance its durability and maintenance in one position, the internal connection was developed. The main characteristic of the internal connection is a prosthetic part placed inside the implant and surrounded with the implant surface below the level of implant platform [62]. The internal hex and internal octagon differ in the design of their geometric features. The internal connection improves the distribution and dissipation of forces, which results in better stability. The larger the platform of the implant, the higher the fatigue load limit [63]. In the internal connection, the vertical height from the implant platform to the top of the abutment is reduced [64]. The screw tightening that attaches the prosthetic abutment to an implant, occurs with elongation and blocking the abutment construction, which increases its stability. The distribution of lateral forces is transferred deep within the implants. The

internal connection is more resistant to screw damage and to wear in comparison with the external connection [65].

6.3. Conical Connection

A conical connection is currently considered to be one of the best. Its main advantage is the load transfer along two conical constructions, that causes limited abutment loading [66,67]. This design provides separation of the interior of an implant from the surrounding tissues, limiting microleakage. The most frequently used type of a conical connection is Morse taper, which ensures integrity between the implant and abutment, with the smallest micromovements observed at a narrow (2°–4°) inclination angle of conical prosthetic abutment [68,69]. Thanks to that, the risk of rapid loosening of the prosthetic construction significantly decreases [70].

6.4. Tube-in-Tube Connection

A tube-in-tube connection is made of two cylinders that allow good load distribution to be transmitted to the implant. If the length of the tube-in-tube connection between the abutment and implant in comparison to its diameter is bigger, it gains higher durability in the long-term of loading the construction of an implant [71,72].

7. Microgap between the Abutment and Implant

The microgap enables bacteria to colonize the connection between an implant and abutment [59]. The aim is to obtain the smallest possible microgap between implant-abutment parts. With a larger microgap the risk of bacterial leakage and rising, so-called the pumping effect, significantly increases. The pumping effect is a phenomenon of bacterial movement inside and outside the connection under the influence of pressure changes. This leads to crestal bone loss around the implants due to bacterial contamination, which incubates in intercellular fluid [73]. The exact fit of the prosthetic abutment to the implant prevents plaque accumulation that can possibly cause inflammation and subsequent soft tissue loss around the implant [74].

Studies show that the implant-abutment microgap is measured between the free edge of the implant and the abutment in a horizontal and vertical position [75]. The presence of microgap is measured with an optical and scanning electron microscope, as well as with microleakage studies [76]. The vertical microgap may vary from less than 10 μm up to even 100 μm. In some studies, microgaps vary from 2.3 to 5.6 μm. In another study, this distance varies from 22.6 to 62.2 μm for vertical and from 27.1 to 16.0 μm for horizontal microgap [64]. It is very difficult to evaluate the average, optimal value of the microgap measurements due to the lack of standardized studies [75].

The cement-retained abutments produce a far smaller microgap in comparison to screw-retained ones. The smallest size of microgap can be observed with the internal conical connection [77,78].

The position of the microgap in relation to the level of the bone crest also plays a role. It was found that moving the microgap coronally away from the bone crest resulted in less bone loss around the implants [79].

The study showed that the microgap magnitude, tested in vitro, may vary depending on the material of the abutment and the abutment manufacturing technique [80]. The smallest microgap was achieved with CAD/CAM fabricated zirconia abutments, as well as the milled Cr-Co abutments.

8. Implant Abutment for Cemented and Screwed Prosthetic Restorations

8.1. Abutments for Cemented Implant-Supported Restorations

Prosthetic restorations are located on abutments in two ways: By cementing or screwing. Cemented prosthetic restorations are often cheaper than screw-retained restorations [81]. The cementing procedure is required for one-piece implants due to the inability to perform screwed restorations. With a precisely carried out cementing procedure, there

is no microgap, in which bacteria can multiply. In addition, there are no complications related to chipping of the ceramics at the fixing screw hole, through which the prosthetic restoration is screwed. On the other hand, in case of cemented restorations it is very important to thoroughly remove the excess cement, which may cause inflammation around the implant. Along with the depth of the restoration up to 3 mm of subgingival, the amount of unremoved excess cement increases. Additionally, the removal of the excess may lead to damage to the connector's structure [82]. There is also a problem with the repair of the prosthetic restoration located by cementation, due to its destruction risk after removal from the prosthetic abutment [83]. All in all, cemented crowns/bridges are not commonly used in modern implant-borne prosthetics due to the inability to obtain full dryness of the operating field and maintaining a sterile implant platform during the cementation procedure [81]. As a result, bacteria that are in the microgap between the prosthetic abutment and the implant can quickly penetrate beyond the connection and consequently cause inflammation. Such bacterial colonization can occur during implantation, exposing the implant, as well as during screwing or cementing the restoration [84].

8.2. Abutments for Screwed Implant-Supported Restorations

Nonetheless, prosthetic restoration on screwed abutments are most often used due to the easier repair and periodic inspection, better hygiene of the restorations, and fewer complications related to the tissues around the implant. Reduced resistance is on the screw with which the prosthetic abutment is screwed to the implant. There is also no cement deposit that can compensate for deformations caused by mismatches in the structure. There can be too much stress on the bone and the implant if the restoration is imprecise [85]. A significantly better fit of the abutment to the implant was observed with machined abutments versus cast abutments. Additionally, the screw is loosened more often and the mobility of the structure is increased [86]. The disadvantages of screw-retained restorations include frequent chipping of the crown ceramics at the fixing screw hole. Taking into account the mechanical properties, a greater susceptibility to cracking of the zirconium structure was observed due to its hardness [87].

It is also possible to combine the cementing and screwing technique, in so-called hybrid restoration. It consists of cementing the restoration on a titanium base and then screwing it intraorally to the implant. As a result, the excess cement can be accurately removed [88]. This solution prevents peri-implantitis, which may constitute 33–100% of failures, when the excessive cement is left behind around the implant abutment and prevents corrosion and galvanism using prefabricated abutments adjacent to the soft tissues [89]. Screw-retained restorations revealed a 16.9% lower level of inflammation in comparison to conventional cemented restorations [90]. Moreover, the success rate of the combined type of restorations were up to 92.4% [91]. Hybrid restoration reduces the risk of damage to the interface between the abutment and implant due to the contact between titanium and titanium. There is no such relationship with a prosthetic abutment made of one part.

9. Implant and Abutment Surface at the Transmucosal Level—Their Influence on Peri-Implant Soft Tissue

The attachment between the mucosa and the dental implants abutment surface depends on the implant chemical composition, surface free-energy, and topography. The surface of implants may have variable topography, that can be modified, i.e., using machining, etching (sulphuric acid, hydrofluoric acid, hydrochloric acid), oxidizing (anodizing, which modifies the microstructure of the surface increasing its roughness), sandblasting (titanium dioxide, aluminium oxide, zirconium dioxide, silicon carbide), and laser [92]. To determine dental implant surface topography, there are several surface roughness parameters which have to be examined. The most commonly evaluated parameters in the studies are Ra (arithmetic medium value of the deviations in relation to the medium line) and Rz (peak-to-valley roughness) parameters [93–95]. The classification of implant neck surface roughness based on the value of Ra parameter regards surface as: Smooth when

Ra is less than 0.5 μm, minimally rough with Ra = 0.5–1.0 μm, moderately rough with Ra = 1.0–2.0 μm, and highly rough with Ra more than 2.0 μm [96–98]. Other studies use the Sa parameter (arithmetic mean of absolute value of the height) to assess the dental implant surface roughness [99–101] and presented a general classification of abutment-surface-roughness (ASR) based on the Sa value. The classification describes the surface as too smooth at Sa < 0.10 μm, optimal when Sa is within the range of 0.15–0.25 μm, and too rough when Sa > 0.35 μm. The values of Sa parameter within ranges either 0.10–0.15 μm or 0.25–0.35 μm depict the surface of tolerable roughness, describing the surface as not too smooth and not too rough, respectively [101].

In general, it was observed that fibroblasts and epithelial cell proliferation on zirconium are higher than on titanium surface. As for titanium alloy surfaces, fibroblasts adhere better to smooth (polished with silicon carbide paper discs or textile discs together with diamond suspension and silicon suspension) rather than to rough surfaces (prepared airborne-particle abrasion with 110 μm alumina particles). Whereas, for zirconium surfaces, the structured surface enhances fibroblast proliferation. For epithelial cells, smooth surfaces (polished or machined) allow for an increase in the proliferation rates [93]. The adherence of soft tissue to the implants is said to ensure a lower number of bacteria and absence of peri-implantitis, which prevents bone loss around implants [44]. Several studies have shown a very good connective tissue alignment to implant surfaces at the transmucosal level that were mechanically machined [102–104]. Machined titanium dental implants obtained the Ra value of 0.65 ± 0.11 μm and Rz of 6.09 ± 0.37 μm [94]. The microgrooves created during the process resulted in smaller apical soft tissues migration. On such surface, a directed growth of fibroblasts was observed together with a long connective tissue alignment and small bone loss [105]. Similar properties as on the machined one were noticed on the sandblasted surface, where collagen fibers were parallel to the surface [106]. The sandblasted titanium dental implants surface revealed the Ra value of 0.75 ± 0.05 μm and Rz = 5.55 ± 0.21 μm [94]. Comparing the neck design of the implant, it has been proven that the smaller depth on probing and bone loss occurred with machining implants with a wide rough neck compared to the rough reduced neck of the implant [107].

Some studies demonstrated the microgap between the epithelial attachment and a transgingival part of the implant with a machined and etched surface. Hydrochloric acid (HCL), sulphuric acid (H_2SO_4), and hydrofluoric acid (HF) are used to etch the implant surface [108]. The acid-etched (with hydrochloric or sulfuric acid solution) titanium dental implants surface exhibit the Ra value of 0.51 ± 0.10 μm and Rz of 5.09 ± 0.46 μm. Whereas, the anodized surface exhibit Ra = 0.87 ± 0.14 μm and Rz = 5.14 ± 0.69 μm [94]. The oxidized and etched surfaces of implants, at the site of soft tissue attachment, showed a smaller epithelial growth and longer connective tissue compared with machining surfaces [109]. The chemically modified etching process allows a thin layer of hydrocarbons and carbonates to establish on the surface. Thanks to that, the received hydroxylated surface initially has a contact angle close to 0, which guarantees very good attachment [110]. In contrast, the oxidized surface allows soft tissue proliferation on an implant surface. The anodic oxidation coating can improve resistance to attrition and corrosion and stability of titanium surface colour. Additionally, pink-shaded anodized titanium enhances the epithelial tissue attachment to the prosthetic abutment surface. However, after 24 h, a lower cellular adhesion to the anodized surface was observed compared with the machining surface [44]. Early bone loss can be affected by producing the polished implant abutment surface, which was replaced in many implant systems with the machining one.

Moreover, the connective tissue has shown the enhanced attachment to laser-microtextured surface of implants and abutments. Namely, clinically less bone loss has been found when laser-microtextured collar implants were used, in comparison with the smooth surfaces, regardless of the loading protocol [111]. The epithelial tissue exhibits better alignment ability to rough than to smooth surfaces. Regrettably, it does not guarantee perfect soft tissue adhesion to the transgingival part of implant or exclude peri-implantitis. Proper (comprehensive) preparation of the surface ensures adhesion of soft tissues and

fibroblasts proliferation, but also osseointegration. Simultaneously, it prevents excessive plaque deposition [112]. On the other hand, the rough surface does not allow for the proper epithelial attachment and increases plaque accumulation. Excessive plaque accumulation results in inflammation of soft tissue surrounding the implant. That is why selecting the appropriate roughness is very important especially for the transmucosal part of the implant-abutment connection. As mentioned before, the average roughness (Sa value) should vary from 0.15–0.25 µm [101]. Below this value, the stable soft tissue attachment will not be maintained. Furthermore, the higher the value of average roughness, the more microbial contamination may occur [101]. In contrast to the soft tissue connection, a higher roughness value determines a larger bone formation. When the roughness increases, the removal torque of implants increases up to the critical value [94,98]. Consequently, low preservation of the marginal bone level with the polished neck of an implant has been proven [113,114].

10. Biological Aspect of Implant-Abutment Connection

10.1. Biological Width

The biological width occurs around implants and natural teeth. It consists of a marginal epithelium surrounding an implant, called epithelial attachment, and connective tissue attachment, in which collagen fibers adhering to the implant surface are situated [104]. It is thought that the epithelium lining the sulcus around the implant has structural and functional features similar to gingival tissue. Soft tissues attach with hemidesmosomes around the implant, however they create much weaker connections than with natural teeth [115]. The keratinized mucosa around the implant has a positive impact on the maintenance of hard and soft tissues, as it prevents bone loss. Initially, bone resorption begins from its cortex. Bone changes can be caused by an excess of cytokines that stimulate osteoblasts or inhibit osteoclasts that affect resorption and apposition of the bone [116]. Moreover, neutrophils, plasma cells, and macrophages can be found around dental implants with bone loss [117]. The cells have a fibroblastic phenotype and lead to the reduction in bone matrix around implants [118]. On the other hand, the increased number of osteocytes was found around immediately loaded implants and it is important in maintaining the bone matrix. In contrast to natural tooth, around implants, transverse collagen fibers are replaced with circumferential fibers surrounding the implants. Circumferential fibers can be found on the first thread of implant. Moreover, by immediately loaded implants more circumferential fibers were found, which are most resistant to compressive forces resulting in high bone-to-implant contact [119,120]. In platform-switched implants the biological width is located more coronally compared with implants with other types of connections [121]. Granulation tissue, which occurs in transgingival connection of soft tissues with the implant, prevents apical connective tissue movement [122].

10.2. Emergence Profile

The emergence profile of implants is an important issue to facilitate favourable aesthetic outcome and maintain peri-implant health. The over-contoured prosthetic abutments causes an initial pressure on interproximal papilla, which leads to ischemia and, in consequence, to bone loss and apical migration of soft tissues [115]. However, a too small abutment in width may lead to an increased plaque and bacteria accumulation [123]. It has been proven, that there is an increased bone loss with convex abutment profile in comparison with the concave profile [106]. The frequent removal of the abutment causes apical migration of soft tissues [124]. Mechanical trauma to soft tissue leads to subsequent bone loss and low soft tissue profile [125]. The platform-switching type of implant-abutment connection influences the emergence profile. Thanks to this concept, the excessive pressure of the abutment on soft tissues can be eliminated. Moreover, it allows for maintaining proper hygiene around implant-supported restoration. A lower number of bacteria has been found at the implant-abutment interface when platform-switching was used, ensuring healthy soft tissues with a proper emergence profile around implants [126,127].

11. Summary

On the market, there are more and more manufacturers offering advanced solutions, which allow decreasing the number of failures and providing longer lasting prosthetic implant-supported restorations. With adequate procedures and correct selection of the system and tools, bone loss can be reduced and soft tissues without pathological changes can be retained. Finding the balance between function and aesthetic in implant rehabilitation is crucial.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data sharing not applicable.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. Moraschini, V.; Poubel, L.A.D.C.; Ferreira, V.F.; Barboza, E.D.S.P. Evaluation of survival and success rates of dental implants reported in longitudinal studies with a follow-up period of at least 10 years: A systematic review. *Int. J. Oral Maxillofac. Surg.* **2015**, *44*, 377–388. [CrossRef]
2. Gómez-de Diego, R.; Mang-de la Rosa, M.D.R.; Romero-Pérez, M.J.; Cutando-Soriano, A.; López-Valverde-centeno, A. Indications and contraindications of dental implants in medically compromised patients: Update. *Med. Oral Patol. Oral Cir. Bucal* **2014**, *19*, e483–e489. [CrossRef] [PubMed]
3. Duttenhoefer, F.; Fuessinger, M.A.; Beckmann, Y.; Schmelzeisen, R.; Groetz, K.A.; Boeker, M. Dental implants in immunocompromised patients: A systematic review and meta-analysis. *Int. J. Implant Dent.* **2019**, *5*. [CrossRef] [PubMed]
4. Ramesh, M.; Arun, R.; Priyadharshini, I. Journal of advanced medical and dental sciences research. *J. Adv. Med. Dent. Sci. Res.* **2018**, *6*, 129–133. [CrossRef]
5. Raikar, S.; Talukdar, P.; Kumari, S.; Panda, S.; Oommen, V.; Prasad, A. Factors affecting the survival rate of dental implants: A retrospective study. *J. Int. Soc. Prev. Community Dent.* **2017**, *7*, 351. [CrossRef]
6. Turri, A.; Rossetti, P.; Canullo, L.; Grusovin, M.; Dahlin, C. Prevalence of peri-implantitis in medically compromised patients and smokers: A systematic review. *Int. J. Oral Maxillofac. Implants* **2016**, *31*, 111–118. [CrossRef] [PubMed]
7. Parihar, A.; Madhuri, S.; Devanna, R.; Sharma, G.; Singh, R.; Shetty, K. Assessment of failure rate of dental implants in medically compromised patients. *J. Fam. Med. Prim. Care* **2020**, *9*, 883. [CrossRef]
8. Donos, N.; Calciolari, E. Dental implants in patients affected by systemic diseases. *Br. Dent. J.* **2014**, *217*, 425–430. [CrossRef]
9. Singh, R.; Parihar, A.; Vaibhav, V.; Kumar, K.; Singh, R.; Jerry, J. A 10 years retrospective study of assessment of prevalence and risk factors of dental implants failures. *J. Fam. Med. Prim. Care* **2020**, *9*, 1617. [CrossRef]
10. Oswal, M.M.; Amasi, U.N.; Oswal, M.S.; Bhagat, A.S. Influence of three different implant thread designs on stress distribution: A three-dimensional finite element analysis. *J. Indian Prosthodont. Soc.* **2016**, *16*, 359–365. [CrossRef]
11. Esposito, M.; Hirsch, J.M.; Lekholm, U.; Thomsen, P. Biological factors contributing to failures of osseointegrated oral implants. (I). Success criteria and epidemiology. *Eur. J. Oral Sci.* **1998**, *106*, 527–551. [CrossRef]
12. Naveau, A.; Shinmyouzu, K.; Moore, C.; Avivi-Arber, L.; Jokerst, J.; Koka, S. Etiology and measurement of peri-implant crestal bone loss (CBL). *J. Clin. Med.* **2019**, *8*, 166. [CrossRef]
13. Baggi, L.; Cappelloni, I.; Di Girolamo, M.; Maceri, F.; Vairo, G. The influence of implant diameter and length on stress distribution of osseointegrated implants related to crestal bone geometry: A three-dimensional finite element analysis. *J. Prosthet. Dent.* **2008**, *100*, 422–431. [CrossRef]
14. Winkler, S.; Morris, H.F.; Ochi, S. Implant survival to 36 months as related to length and diameter. *Ann. Periodontol.* **2000**, *5*, 22–31. [CrossRef]

15. Chung, D.M.; Oh, T.J.; Lee, J.; Misch, C.E.; Wang, H.L. Factors affecting late implant bone loss: A retrospective analysis. *J. Prosthet. Dent.* **2007**, *98*, 215. [CrossRef]

16. Monje, A.; Suarez, F.; Galindo-Moreno, P.; García-Nogales, A.; Fu, J.H.; Wang, H.L. A systematic review on marginal bone loss around short dental implants (<10 mm) for implant-supported fixed prostheses. *Clin. Oral Implants Res.* **2014**, *25*, 1119–1124. [CrossRef]

17. Eazhil, R.; Swaminathan, S.; Gunaseelan, M.; Kannan, G.; Alagesan, C. Impact of implant diameter and length on stress distribution in osseointegrated implants: A 3D FEA study. *J. Int. Soc. Prev. Community Dent.* **2016**, *6*, 590–596. [CrossRef]

18. Broggini, N.; McManus, L.M.; Hermann, J.S.; Medina, R.; Schenk, R.K.; Buser, D.; Cochran, D.L. Peri-implant inflammation defined by the implant-abutment interface. *J. Dent. Res.* **2006**, *85*, 473–478. [CrossRef]

19. Lekholm, U.; Zarb, G. Patient selection and preparation. In *Tissue Integrated Prostheses: Osseointegration in Clinical Dentistry*; Branemark, P.-I., Zarb, G., Alberktsson, T., Eds.; Quintessence Publishing Company: Chicago, IL, USA, 1985; pp. 199–209. ISBN 0867151293.

20. Abrahamsson, I.; Berglundh, T. Effects of different implant surfaces and designs on marginal bone-level alterations: A review. *Clin. Oral Implants Res.* **2009**, *20*, 207–215. [CrossRef]

21. Li, J.; Yin, X.; Huang, L.; Mouraret, S.; Brunski, J.B.; Cordova, L.; Salmon, B.; Helms, J.A. Relationships among bone quality, implant osseointegration, and wnt signaling. *J. Dent. Res.* **2017**, *96*, 822–831. [CrossRef]

22. Güven, S.S.; Cabbar, F.; Güler, N. Local and systemic factors associated with marginal bone loss around dental implants: A retrospective clinical study. *Quintessence Int.* **2020**, *51*, 128–141. [CrossRef]

23. Eshkol-Yogev, I.; Tandlich, M.; Shapira, L. Effect of implant neck design on primary and secondary implant stability in the posterior maxilla: A prospective randomized controlled study. *Clin. Oral Implants Res.* **2019**, *30*, 1220–1228. [CrossRef] [PubMed]

24. Prathapachandran, J.; Suresh, N. Management of peri-implantitis. *Dent. Res. J.* **2012**, *9*, 516. [CrossRef] [PubMed]

25. Koo, K.T.; Khoury, F.; Leander Keeve, P.; Schwarz, F.; Ramanauskaite, A.; Sculean, A.; Romanos, G. Implant surface decontamination by surgical treatment of periimplantitis: A literature review. *Implant Dent.* **2019**, *28*, 173–176. [CrossRef] [PubMed]

26. Hanif, A.; Qureshi, S.; Sheikh, Z.; Rashid, H. Complications in implant dentistry. *Eur. J. Dent.* **2017**, *11*, 135–140. [CrossRef]

27. Rashid, H.; Sheikh, Z.; Vohra, F.; Hanif, A.; Glogauer, M. Peri-implantitis: A review of the disease and report of a case treated with allograft to achieve bone regeneration. *Dent. Open J.* **2015**, *2*, 87–97. [CrossRef]

28. Roca-Millan, E.; Estrugo-Devesa, A.; Merlos, A.; Jané-Salas, E.; Vinuesa, T.; López-López, J. Systemic antibiotic prophylaxis to reduce early implant failure: A systematic review and meta-analysis. *Antibiotics* **2021**, *10*, 698. [CrossRef]

29. Annibali, S.; Ripari, M.; LA Monaca, G.; Tonoli, F.; Cristalli, M.P. Local complications in dental implant surgery: Prevention and treatment. *Oral Implantol.* **2008**, *1*, 21–33.

30. Shafie, H.R.; White, B.A. Implant Abutment Materials. In *Clinical and Laboratory Manual of Dental Implant Abutments*; John Wiley & Sons, Ltd.: Oxford, UK, 2014; pp. 1–16.

31. Lim, J.Y.; Liu, X.; Vogler, E.A.; Donahue, H.J. Systematic variation in osteoblast adhesion and phenotype with substratum surface characteristics. *J. Biomed. Mater. Res. Part A* **2004**, *68*, 504–512. [CrossRef]

32. Mehl, C.; Gaβling, V.; Schultz-Langerhans, S.; Açil, Y.; Bähr, T.; Wiltfang, J.; Kern, M. Influence of four different abutment materials and the adhesive joint of two-piece abutments on cervical implant bone and soft tissue. *Int. J. Oral Maxillofac. Implants* **2016**, *31*, 1264–1272. [CrossRef]

33. Welander, M.; Abrahamsson, I.; Berglundh, T. The mucosal barrier at implant abutments of different materials. *Clin. Oral Implants Res.* **2008**, *19*, 635–641. [CrossRef]

34. Sailer, I.; Philipp, A.; Zembic, A.; Pjetursson, B.E.; Hämmerle, C.H.F.; Zwahlen, M. A systematic review of the performance of ceramic and metal implant abutments supporting fixed implant reconstructions. *Clin. Oral Implants Res.* **2009**, *20*, 4–31. [CrossRef]

35. Osman, R.B.; Swain, M.V. A critical review of dental implant materials with an emphasis on titanium versus zirconia. *Materials* **2015**, *8*, 932–958. [CrossRef]

36. Spies, B.C.; Sauter, C.; Wolkewitz, M.; Kohal, R.J. Alumina reinforced zirconia implants: Effects of cyclic loading and abutment modification on fracture resistance. *Dent. Mater.* **2015**, *31*, 262–272. [CrossRef] [PubMed]

37. Bharate, V.; Kumar, Y.; Koli, D.; Pruthi, G.; Jain, V. Effect of different abutment materials (zirconia or titanium) on the crestal bone height in 1 year: Bone loss with implant abutment materials. *J. Oral Biol. Craniofacial Res.* **2020**, *10*, 372–374. [CrossRef]

38. Baldassarri, M.; Hjerppe, J.; Romeo, D.; Fickl, S.; Thompson, V.P.; Stappert, C.F.J. Marginal accuracy of three implant-ceramic abutment configurations. *Int. J. Oral Maxillofac. Implants* **2012**, *27*, 537–543. [PubMed]

39. Cavusoglu, Y.; Akça, K.; Gürbüz, R.; Cavit Cehreli, M. A pilot study of joint stability at the zirconium or titanium abutment/titanium implant interface. *Int. J. Oral Maxillofac. Implants* **2014**, *29*, 338–343. [CrossRef]

40. Prithviraj, D.R.; Gupta, V.; Muley, N.; Sandhu, P. One-piece implants: Placement timing, surgical technique, loading protocol, and marginal bone loss. *J. Prosthodont.* **2013**, *22*, 237–244. [CrossRef] [PubMed]

41. Blank, E.; Grischke, J.; Winkel, A.; Eberhard, J.; Kommerein, N.; Doll, K.; Yang, I.; Stiesch, M. Evaluation of biofilm colonization on multi-part dental implants in a rat model. *BMC Oral Health* **2021**, *21*. [CrossRef]

42. Hahn, J.A. Clinical and radiographic evaluation of one-piece implants used for immediate function. *J. Oral Implantol.* **2007**, *33*, 152–155. [CrossRef]

43. Östman, P.O.; Hellman, M.; Albrektsson, T.; Sennerby, L. Direct loading of Nobel Direct® and Nobel Perfect® one-piece implants: A 1-year prospective clinical and radiographic study. *Clin. Oral Implants Res.* **2007**, *18*, 409–418. [CrossRef]

44. Dorkhan, M.; Yücel-Lindberg, T.; Hall, J.; Svensäter, G.; Davies, J.R. Adherence of human oral keratinocytes and gingival fibroblasts to nano-structured titanium surfaces. *BMC Oral Health* **2014**, *14*, 75. [CrossRef]

45. Palacios-Garzón, N.; Velasco-Ortega, E.; López-López, J. Bone loss in implants placed at subcrestal and crestal level: A systematic review and meta-analysis. *Materials* **2019**, *12*, 154. [CrossRef] [PubMed]

46. Piattelli, A.; Vrespa, G.; Petrone, G.; Iezzi, G.; Annibali, S.; Scarano, A. Role of the microgap between implant and abutment: A retrospective histologic evaluation in monkeys. *J. Periodontol.* **2003**, *74*, 346–352. [CrossRef] [PubMed]

47. Sasada, Y.; Cochran, D. Implant-abutment connections: A review of biologic consequences and peri-implantitis implications. *Int. J. Oral Maxillofac. Implants* **2017**, *32*, 1296–1307. [CrossRef] [PubMed]

48. Wallner, G.; Rieder, D.; Wichmann, M.; Heckmann, S. Peri-implant bone loss of tissue-level and bone-level implants in the esthetic zone with gingival biotype analysis. *Int. J. Oral Maxillofac. Implants* **2018**, *33*, 1119–1125. [CrossRef] [PubMed]

49. Lopez, M.A.; Bassi, M.A.; Confalone, L.; Gaudio, R.M.; Lombardo, L.; Lauritano, D. Retrospective study on bone-level and soft-Tissue-level cylindrical implants. *J. Biol. Regul. Homeost. Agents* **2016**, *30*, 43–48. [PubMed]

50. Lazzara, R.J.; Porter, S.S. Platform switching: A new concept in implant dentistry for controlling postrestorative crestal bone levels. *Int. J. Periodontics Restorative Dent.* **2006**, *26*, 9–17. [CrossRef] [PubMed]

51. Zandim-Barcelos, D.L.; De Carvalho, G.G.; Sapata, V.M.; Villar, C.C.; Hämmerle, C.; Romito, G.A. Implant-based factor as possible risk for peri-implantitis. *Braz. Oral Res.* **2019**, *33*, 1–10. [CrossRef] [PubMed]

52. DI Girolamo, M.; Calcaterra, R.; DI Gianfilippo, R.; Arcuri, C.; Baggi, L. Bone level changes around platform switching and platform matching implants: A systematic review with meta-analysis. *Oral Implantol.* **2016**, *9*, 1–10. [CrossRef]

53. Yang, T.-C.; Maeda, Y. The biomechanical effect of platform switching on external- and internal-connection implants. *Int. J. Oral Maxillofac. Implants* **2013**, *28*, 143–147. [CrossRef] [PubMed]

54. Enkling, N.; Jöhren, P.; Katsoulis, J.; Bayer, S.; Jervøe-Storm, P.M.; Mericske-Stern, R.; Jepsen, S. Influence of platform switching on bone-level alterations: A three-year randomized clinical trial. *J. Dent. Res.* **2013**, *92*, 139S–145S. [CrossRef] [PubMed]

55. Farronato, D.; Santoro, G.; Canullo, L.; Botticelli, D.; Maiorana, C.; Lang, N.P. Establishment of the epithelial attachment and connective tissue adaptation to implants installed under the concept of "platform switching": A histologic study in minipigs. *Clin. Oral Implants Res.* **2012**, *23*, 90–94. [CrossRef]

56. Alonso-González, R.; Aloy-Prósper, A.; Peñarrocha-Oltra, D.; Peñarrocha-Diago, M.A.; Peñarrocha-Diago, M. Marginal bone loss in relation to platform switching implant insertion depth: An update. *J. Clin. Exp. Dent.* **2012**, *4*. [CrossRef]

57. Pita, M.S.; Anchieta, R.B.; Barão, V.A.R.; Garcia, I.R.; Pedrazzi, V.; Assunção, W.G. Prosthetic platforms in implant dentistry. *J. Craniofac. Surg.* **2011**, *22*, 2327–2331. [CrossRef]

58. Brånemark, P.I.; Hansson, B.O.; Adell, R.; Breine, U.; Lindström, J.; Hallén, O.; Ohman, A. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. *Scand. J. Plast. Reconstr. Surg. Suppl.* **1977**, *16*, 1–132.

59. Lorenzoni, F.C.; Coelho, P.G.; Bonfante, G.; Carvalho, R.M.; Silva, N.R.F.A.; Suzuki, M.; Silva, T.L.; Bonfante, E.A. Sealing capability and SEM observation of the implant-abutment interface. *Int. J. Dent.* **2011**, *2011*. [CrossRef] [PubMed]

60. D'Ercole, S.; Scarano, A.; Perrotti, V.; Mulatinho, J.; Piattelli, A.; Iezzi, G.; Tripodi, D. Implants with internal hexagon and conical implant-abutment connections: An in vitro study of the bacterial contamination. *J. Oral Implantol.* **2014**, *40*, 31–36. [CrossRef]

61. Article, R. Evolution of External and internal implant to. *Int. J. Oral Implantol. Clin. Res.* **2012**, *3*, 122–129. [CrossRef]

62. Gaviria, L.; Salcido, J.P.; Guda, T.; Ong, J.L. Current trends in dental implants. *J. Korean Assoc. Oral Maxillofac. Surg.* **2014**, *40*, 50. [CrossRef] [PubMed]

63. Nicolas-Silvente, A.I.; Velasco-Ortega, E.; Ortiz-Garcia, I.; Jimenez-Guerra, A.; Monsalve-Guil, L.; Ayuso-Montero, R.; Gil, J.; Lopez-Lopez, J. Influence of connection type and platform diameter on titanium dental implants fatigue: Non-axial loading cyclic test analysis. *Int. J. Environ. Res. Public Health* **2020**, *17*, 8988. [CrossRef] [PubMed]

64. Tsuge, T.; Hagiwara, Y.; Matsumura, H. Marginal fit and microgaps of implant-abutment interface with internal anti-rotation configuration. *Dent. Mater. J.* **2008**, *27*, 29–34. [CrossRef] [PubMed]

65. Asvanund, P.; Morgano, S.M. Photoelastic stress analysis of external versus internal implant-abutment connections. *J. Prosthet. Dent.* **2011**, *106*, 266–271. [CrossRef]

66. Black, D.L.; Turkyilmaz, I.; Lien, W.; Chong, C.H. Evaluation of the sealing capability of the internal conical connections of implants with titanium and zirconia abutments. *J. Contemp. Dent. Pract.* **2017**, *18*, 915–922. [CrossRef]

67. Macedo, J.P.; Pereira, J.; Vahey, B.R.; Henriques, B.; Benfatti, C.A.M.; Magini, R.S.; López-López, J.; Souza, J.C.M. Morse taper dental implants and platform switching: The new paradigm in oral implantology. *Eur. J. Dent.* **2016**, *10*, 148–154. [CrossRef]

68. Gil, F.J.; Herrero-Climent, M.; Lázaro, P.; Rios, J.V. Implant-abutment connections: Influence of the design on the microgap and their fatigue and fracture behavior of dental implants. *J. Mater. Sci. Mater. Med.* **2014**, *25*, 1825–1830. [CrossRef]

69. Schmitt, C.M.; Nogueira-Filho, G.; Tenenbaum, H.C.; Lai, J.Y.; Brito, C.; Döring, H.; Nonhoff, J. Performance of conical abutment (Morse Taper) connection implants: A systematic review. *J. Biomed. Mater. Res. Part A* **2014**, *102*, 552–574. [CrossRef]

70. Ceruso, F.M.; Barnaba, P.; Mazzoleni, S.; Ottria, L.; Gargari, M.; Zuccon, A.; Bruno, G.; Di Fiore, A. Implant-abutment connections on single crowns: A systematic review. *ORAL Implantol.* **2017**, *10*, 349–353. [CrossRef]

71. Steinebrunner, L.; Wolfart, S.; Ludwig, K.; Kern, M. Implant-abutment interface design affects fatigue and fracture strength of implants. *Clin. Oral Implants Res.* **2008**, *19*, 1276–1284. [CrossRef]

72. Balik, A.; Karatas, M.O.; Keskin, H. Effects of different abutment connection designs on the stress distribution around five different implants: A 3-dimensional finite element analysis. *J. Oral Implantol.* **2012**, *38*, 491–496. [CrossRef]

73. Nassar, H.I.; Abdalla, M.F. Bacterial leakage of different internal implant/abutment connection. *Futur. Dent. J.* **2015**, *1*, 1–5. [CrossRef]

74. Souza, A.B.; Alshihri, A.M.; Kämmerer, P.W.; Araújo, M.G.; Gallucci, G.O. Histological and micro-CT analysis of peri-implant soft and hard tissue healing on implants with different healing abutments configurations. *Clin. Oral Implants Res.* **2018**, *29*, 1007–1015. [CrossRef]

75. Kano, S.C.; Binon, P.P.; Curtis, D.A. A classification system to measure the implant-abutment microgap. *Int. J. Oral Maxillofac. Implants* **2007**, *22*, 879–885.

76. Kofron, M.D.; Carstens, M.; Fu, C.; Wen, H.B. In vitro assessment of connection strength and stability of internal implant-abutment connections. *Clin. Biomech.* **2019**, *65*, 92–99. [CrossRef]

77. Assenza, B.; Tripodi, D.; Scarano, A.; Perrotti, V.; Piattelli, A.; Iezzi, G.; D'Ercole, S. Bacterial leakage in implants with different implant–abutment connections: An In Vitro Study. *J. Periodontol.* **2012**, *83*, 491–497. [CrossRef]

78. He, Y.; Fok, A.; Aparicio, C.; Teng, W. Contact analysis of gap formation at dental implant-abutment interface under oblique loading: A numerical-experimental study. *Clin. Implant Dent. Relat. Res.* **2019**, *21*, 741–752. [CrossRef]

79. Hermann, J.S.; Schoolfield, J.D.; Schenk, R.K.; Buser, D.; Cochran, D.L. Influence of the size of the microgap on crestal bone changes around titanium implants. A histometric evaluation of unloaded non-submerged implants in the canine mandible. *J. Periodontol.* **2001**, *72*, 1372–1383. [CrossRef]

80. Molinero-Mourelle, P.; Cascos-Sanchez, R.; Yilmaz, B.; Lam, W.Y.H.; Pow, E.H.N.; Del Río Highsmith, J.; Gómez-Polo, M. Effect of fabrication technique on the microgap of CAD/CAM cobalt-chrome and zirconia abutments on a conical connection implant: An in vitro study. *Materials* **2021**, *14*, 2348. [CrossRef]

81. Shadid, R.; Sadaqa, N. A comparison between screw-and cement-retained implant prostheses. A literature review. *J. Oral Implantol.* **2012**, *38*, 298–307. [CrossRef]

82. Linkevicius, T.; Vindasiute, E.; Puisys, A.; Peciuliene, V. The influence of margin location on the amount of undetected cement excess after delivery of cement-retained implant restorations. *Clin. Oral Implants Res.* **2011**, *22*, 1379–1384. [CrossRef]

83. Shi, J.Y.; Ni, J.; Zhuang, L.F.; Zhang, X.M.; Fan, L.F.; Lai, H.C. Peri-implant conditions and marginal bone loss around cemented and screw-retained single implant crowns in posterior regions: A retrospective cohort study with up to 4 years follow-up. *PLoS ONE* **2018**, *13*, e0191717. [CrossRef]

84. Heo, Y.-K.; Lim, Y.-J. A newly designed screw- and cement-retained prosthesis and its abutments. *Int. J. Prosthodont.* **2015**, *28*, 612–614. [CrossRef]

85. Kim, S.G.; Chung, C.H.; Son, M.K. Effect of cement washout on loosening of abutment screws and vice versa in screw- and cement- retained implant-supported dental prosthesis. *J. Adv. Prosthodont.* **2015**, *7*, 207–213. [CrossRef]

86. Kano, S.C.; Binon, P.; Bonfante, G.; Curtis, D.A. Effect of casting procedures on screw loosening in UCLA-type abutments. *J. Prosthodont.* **2006**, *15*, 77–81. [CrossRef]

87. Kourtis, S.; Damanaki, M.; Kaitatzidou, S.; Kaitatzidou, A.; Roussou, V. Loosening of the fixing screw in single implant crowns: Predisposing factors, prevention and treatment options. *J. Esthet. Restor. Dent.* **2017**, *29*, 233–246. [CrossRef]

88. Abdelhamed, M.I.; Galley, J.D.; Bailey, M.T.; Johnston, W.M.; Holloway, J.; Mcglumphy, E.; Leblebicioglu, B. A comparison of zirconia and titanium abutments for microleakage. *Clin. Implant Dent. Relat. Res.* **2015**, *17*, e643–e651. [CrossRef]

89. Ongun, S.; Kurtulmus-Yilmaz, S.; Meriç, G.; Ulusoy, M. A comparative study on the mechanical properties of a polymer-infiltrated ceramic-network material used for the fabrication of hybrid abutment. *Materials* **2018**, *11*, 1681. [CrossRef]

90. Agustín-Panadero, R.; Bustamante-Hernández, N.; Labaig-Rueda, C.; Fons-Font, A.; Fernández-Estevan, L.; Solá-Ruíz, M.F. Influence of biologically oriented preparation technique on peri-implant tissues; prospective randomized clinical trial with three-year follow-up. Part II: Soft tissues. *J. Clin. Med.* **2019**, *8*, 2223. [CrossRef]

91. Mangano, F.; Margiani, B.; Admakin, O. A novel full-digital protocol (SCAN-PLAN-MAKE-DONE®) for the design and fabrication of implant-supported monolithic translucent zirconia crowns cemented on customized hybrid abutments: A retrospective clinical study on 25 patients. *Int. J. Environ. Res. Public Health* **2019**, *16*, 317. [CrossRef]

92. Cervino, G.; Fiorillo, L.; Iannello, G.; Santonocito, D.; Risitano, G.; Cicciù, M. Sandblasted and acid etched titanium dental implant surfaces systematic review and confocal microscopy evaluation. *Materials* **2019**, *12*, 1763. [CrossRef]

93. Nothdurft, F.P.; Fontana, D.; Ruppenthal, S.; May, A.; Aktas, C.; Mehraein, Y.; Lipp, P.; Kaestner, L. Differential behavior of fibroblasts and epithelial cells on structured implant abutment materials: A comparison of materials and surface topographies. *Clin. Implant Dent. Relat. Res.* **2015**, *17*, 1237–1249. [CrossRef]

94. Elias, C.N.; Oshida, Y.; Lima, J.H.C.; Muller, C.A. Relationship between surface properties (roughness, wettability and morphology) of titanium and dental implant removal torque. *J. Mech. Behav. Biomed. Mater.* **2008**, *1*, 234–242. [CrossRef]

95. da Cruz, M.B.; Marques, J.F.; Fernandes, B.F.; Costa, M.; Miranda, G.; da Mata, A.D.S.P.; Carames, J.M.M.; Silva, F.S. Gingival fibroblasts behavior on bioactive zirconia and titanium dental implant surfaces produced by a functionally graded technique. *J. Appl. Oral Sci.* **2020**, *28*, 1–10. [CrossRef]

96. Nicolas-Silvente, A.I.; Velasco-Ortega, E.; Ortiz-Garcia, I.; Monsalve-Guil, L.; Gil, J.; Jimenez-Guerra, A. Influence of the titanium implant surface treatment on the surface roughness and chemical composition. *Materials* **2020**, *13*, 314. [CrossRef]

97. Del Fabbro, M.; Taschieri, S.; Canciani, E.; Addis, A.; Musto, F.; Weinstein, R.; Dellavia, C. Osseointegration of titanium implants with different rough surfaces: A histologic and histomorphometric study in an adult minipig model. *Implant Dent.* **2017**, *26*, 357–366. [CrossRef]

98. Albrektsson, T.; Wennerberg, A. Oral implant surfaces: Part 1–review focusing on topographic and chemical properties of different surfaces and in vivo responses to them. *Int. J. Prosthodont.* **2004**, *17*, 536–543. [PubMed]

99. Naves, M.; Menezes, H.; Magalhães, D.; Ferreira, J.; Ribeiro, S.; de Mello, J.; Costa, H. Effect of macrogeometry on the surface topography of dental implants. *Int. J. Oral Maxillofac. Implants* **2015**, *30*, 789–799. [CrossRef]

100. Al-Nawas, B.; Götz, H. Three-dimensional topographic and metrologic evaluation of dental implants by confocal laser scanning microscopy. *Clin. Implant Dent. Relat. Res.* **2003**, *5*, 176–183. [CrossRef] [PubMed]

101. Gehrke, P.; Tabellion, A.; Fischer, C. Microscopical and chemical surface characterization of CAD/CAM zircona abutments after different cleaning procedures. A qualitative analysis. *J. Adv. Prosthodont.* **2015**, *7*, 151. [CrossRef] [PubMed]

102. Canullo, L.; Menini, M.; Santori, G.; Rakic, M.; Sculean, A.; Pesce, P. Titanium abutment surface modifications and peri-implant tissue behavior: A systematic review and meta-analysis. *Clin. Oral Investig.* **2020**, *24*, 1113–1124. [CrossRef]

103. Blázquez-Hinarejos, M.; Ayuso-Montero, R.; Álvarez-López, J.M.; Manzanares-Céspedes, M.C.; López-López, J. Histological differences in the adherence of connective tissue to laser-treated abutments and standard abutments for dental implants. An experimental pilot study in humans. *Med. Oral Patol. Oral Cir. Bucal* **2017**, *22*, e774–e779. [CrossRef]

104. Ivanovski, S.; Lee, R. Comparison of peri-implant and periodontal marginal soft tissues in health and disease. *Periodontology 2000* **2018**, *76*, 116–130. [CrossRef]

105. Sanz-Martín, I.; Sanz-Sánchez, I.; Carrillo de Albornoz, A.; Figuero, E.; Sanz, M. Effects of modified abutment characteristics on peri-implant soft tissue health: A systematic review and meta-analysis. *Clin. Oral Implants Res.* **2018**, *29*, 118–129. [CrossRef]

106. Canullo, L.; Pesce, P.; Patini, R.; Antonacci, D.; Tommasato, G. What are the effects of different abutment morphologies on peri-implant hard and soft tissue behavior? A systematic review and meta-analysis. *Int. J. Prosthodont.* **2020**, *33*, 297–306. [CrossRef]

107. Montemezzi, P.; Ferrini, F.; Pantaleo, G.; Gherlone, E.; Capparè, P. Dental implants with different neck design: A prospective clinical comparative study with 2-year follow-up. *Materials* **2020**, *13*, 1029. [CrossRef]

108. Hung, K.Y.; Lin, Y.C.; Feng, H.P. The effects of acid etching on the nanomorphological surface characteristics and activation energy of titanium medical materials. *Materials* **2017**, *10*, 1164. [CrossRef]

109. Canullo, L.; Annunziata, M.; Pesce, P.; Tommasato, G.; Nastri, L.; Guida, L. Influence of abutment material and modifications on peri-implant soft-tissue attachment: A systematic review and meta-analysis of histological animal studies. *J. Prosthet. Dent.* **2020**, 1–11. [CrossRef]

110. Schwarz, F.; Ferrari, D.; Herten, M.; Mihatovic, I.; Wieland, M.; Sager, M.; Becker, J. Effects of surface hydrophilicity and microtopography on early stages of soft and hard tissue integration at non-submerged titanium implants: An immunohistochemical study in dogs. *J. Periodontol.* **2007**, *78*, 2171–2184. [CrossRef]

111. Guarnieri, R.; Serra, M.; Bava, L.; Grande, M.; Farronato, D.; Iorio-Siciliano, V. The impact of a laser-microtextured collar on crestal bone level and clinical parameters under various placement and loading protocols. *Int. J. Oral Maxillofac. Implants* **2014**, *29*, 354–363. [CrossRef]

112. Nicholson, J.W. Titanium Alloys for Dental Implants: A Review. *Prosthesis* **2020**, *2*, 100–116. [CrossRef]

113. Aloy-Prósper, A.; Maestre-Ferrín, L.; Peñarrocha-Oltra, D.; Peñarrocha-Diago, M. Marginal bone loss in relation to the implant neck surface: An update. *Med. Oral Patol. Oral Cir. Bucal* **2011**, *16*, 365–368. [CrossRef]

114. Zitzmann, N.U.; Abrahamsson, I.; Berglundh, T.; Lindhe, J. Soft tissue reactions to plaque formation at implant abutments with different surface topography: An experimental study in dogs. *J. Clin. Periodontol.* **2002**, *29*, 456–461. [CrossRef]

115. Manicone, P.F.; Raffaelli, L.; Ghassemian, M.; D'Addona, A. Soft and hard tissue management in implant therapy—Part II: Prosthetic concepts. *Int. J. Biomater.* **2012**, *2012*, 356817. [CrossRef]

116. Nowzari, H.; Yi, K.; Chee, W.; Rich, S.K. Immunology, microbiology, and virology following placement of NobelPerfectscalloped dental implants: Analysis of a case series. *Clin. Implant Dent. Relat. Res.* **2008**, *10*, 157–165. [CrossRef]

117. Galárraga-Vinueza, M.E.; Tangl, S.; Bianchini, M.; Magini, R.; Obreja, K.; Gruber, R.; Schwarz, F. Histological characteristics of advanced peri-implantitis bone defects in humans. *Int. J. Implant Dent.* **2020**, *6*. [CrossRef]

118. Schminke, B.; Vom Orde, F.; Gruber, R.; Schliephake, H.; Bürgers, R.; Miosge, N. The pathology of bone tissue during peri-implantitis. *J. Dent. Res.* **2015**, *94*, 354–361. [CrossRef]

119. Tumedei, M.; Piattelli, A.; Degidi, M.; Mangano, C.; Iezzi, G. A narrative review of the histological and histomorphometrical evaluation of the peri-implant bone in loaded and unloaded dental implants. A 30-year experience (1988–2018). *Int. J. Environ. Res. Public Health* **2020**, *17*, 2088. [CrossRef]

120. Goracci, C.; Sadek, F.T.; Monticelli, F.; Cardoso, P.E.C.; Ferrari, M. Microtensile bond strength of self-etching adhesives to enamel and dentin. *J. Adhes. Dent.* **2004**, *6*, 313–318.

121. Rodríguez-Ciurana, X.; Vela-Nebot, X.; Segalà-Torres, M.; Rodado-Alonso, C.; Méndez-Blanco, V.; Mata-Bugueroles, M. Biomechanical repercussions of bone resorption related to biologic width: A finite element analysis of three implant-abutment configurations. *Int. J. Periodontics Restorative Dent.* **2009**, *29*, 479–487. [CrossRef]

122. Al Rezk, F.; Trimpou, G.; Lauer, H.-C.; Weigl, P.; Krockow, N. Response of soft tissue to different abutment materials with different surface topographies: A review of the literature. *Gen. Dent.* **2018**, *66*, 18–25.

123. Delgado-Ruiz, R.; Romanos, G. Potential causes of titanium particle and ion release in implant dentistry: A systematic review. *Int. J. Mol. Sci.* **2018**, *19*, 3585. [CrossRef]

124. Molina, A.; Sanz-Sánchez, I.; Martín, C.; Blanco, J.; Sanz, M. The effect of one-time abutment placement on interproximal bone levels and peri-implant soft tissues: A prospective randomized clinical trial. *Clin. Oral Implants Res.* **2017**, *28*, 443–452. [CrossRef]
125. Bressan, E.; Grusovin, M.G.; D'Avenia, F.; Neumann, K.; Sbricoli, L.; Luongo, G.; Esposito, M. The influence of repeated abutment changes on peri-implant tissue stability: 3-year post-loading results from a multicentre randomised controlled trial. *Eur. J. Oral Implantol.* **2017**, *10*, 373–390.
126. Dornbush, J.R.; Reiser, G.M.; Ho, D.K. Platform switching and abutment emergence profile modification on peri-implant soft tissue. *Alpha Omegan* **2014**, *107*, 28–32.
127. Canullo, L.; Pellegrini, G.; Allievi, C.; Trombelli, L.; Annibali, S.; Dellavia, C. Soft tissues around long-term platform switching implant restorations: A histological human evaluation. Preliminary results. *J. Clin. Periodontol.* **2011**, *38*, 86–94. [CrossRef]