Ceramic Implant Rehabilitation: Consensus Statements from Joint Congress for Ceramic Implantology: Consensus Statements on Ceramic Implant

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The objectives of the study group focused on the following main topics related to the performance of 1- and 2-piece ceramic implants: defining bone-implant-contact percentages and its measurement methods, evaluating the pink esthetic score as an esthetic outcome parameter after immediate implantation, recognizing the different results of ceramic implant designs as redefined by the German Association of Oral Implantology, incorporating the patient report outcome measure to include satisfaction and improvement in oral health–related quality of life, and conducting preclinical studies to address existing gaps in ceramic implants. During the Joint Congress for Ceramic Implantology (2022), the study group evaluated 17 clinical trials published between 2015 and 2021. After extensive discussions and multiple closed sessions, consensus statements and recommendations were developed, incorporating all approved modifications. A 1-piece implant design features a coronal part that is fused to the implant body or interfaces with the postabutment restoration platform, undergoing transmucosal healing. Long-term evaluations of this implant design are supported by established favorable clinical evidence. Inaccuracies in the pink esthetic score and bone-implant-contact percentages were managed by establishing control groups for preclinical studies and randomizing clinical trials. The patient-reported outcome measures were adjusted to include an individual visual analog scale, collected from each clinical study, that quantified improved oral health and quality of life. Preclinical investigations should focus on examining the spread of ceramic debris and the impact of heat generation on tissue and cellular levels during drilling. Further technical advancements should prioritize wound management and developing safe drilling protocols.

Key Words: bone-implant-contact, ceramic implants, heat generation, immediate implantation, pink esthetic score, visual analogue scale

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https://doi.org/10.1563/aaid-joi-D-23-00083

INTRODUCTION

On October 14, 2022, the study group convened to develop statements and recommendations for clinicians and researchers regarding future studies on ceramic implants. The scientific foundation for these decisions was established during the Academy of Osseointegration Summit meeting held in February 2022, at which 17 relevant scientific articles were selected and reviewed.[1–17]

Knowledge of clinical and evidence-based advancements in implant dentistry has led to discussions on critical topics among a group of esteemed experts to outline future studies in disease-associated ceramic implant rehabilitation.

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Since the introduction of zirconia implants to the market, their use in the esthetic zone has been considered an ideal alternative to titanium implants. Initial concerns regarding material strength, osseointegration, and limited designs and protocols have hampered their acceptability in the mainstream implant community. However, the availability of improved options, refined techniques, documented osseointegration, and excellent esthetic clinical outcomes achieved with zirconia implants have firmly established them as credible alternatives to titanium.

Today's high esthetic standards and concerns about titanium sensitivity and corrosion-related diseases have increased the demand for titanium-free restorations.[2,18] Consequently, bioceramics, such as zirconia, have been proposed as potential alternatives.[19] From a biological point of view, zirconia demonstrates a low affinity to bacterial plaque,[9] minimal inflammatory infiltrate, and good soft tissue integration.[15,20] These properties may lower the risk of peri-implant diseases. In addition, numerous reviews highlight the evolution of zirconia-based implant systems. The advancements in surface modifications, thread design, implant shape, and surgical protocols confirm a clinical survival rate above 97% after a follow-up period of 80 months.[10,21] In parallel with the evolution of ceramic implants, there has been a significant expansion in our understanding of osseointegration and wound management processes.

However, it is critical to align the efforts in determining future studies and focus on predicting ceramic implant-associated diseases. Many complications can be avoided with current technological advancements, such as the digitization of treatment processes ranging from diagnosis and implant design to prosthesis planning. This presents an opportunity to conduct future clinical approaches focused not only on functional and esthetic reconstruction, but also on tissue regeneration and improving the patient's quality of life.

Therefore, during the Joint Congress for Ceramic Implantology, 2022, the scientific core group dealt with specific topics. The main issues discussed were the definition of bone-implant-contact percentage (BIC%) and methods for its measurement as a critical parameter to assess the quality of osseointegration in long-term analyses. The pink esthetic score (PES)[22,23] was also examined as a parameter for esthetic outcome following immediate implantation along with determining the appropriate timing for such evaluations. The German Association of Oral Implantology (DGI) revised directives to differentiate between 1- and 2-piece implant designs and evaluate their indications and success rates. This study aimed to comprehensively understand peri-implant tissue health and survival in ceramic implants, designed for placement at the tissue level (1-piece) with transmucosal healing, contrasting them with implants placed at the bone level (2-piece), which undergo subgingival healing.[24,25] An individual visual analog scale (VAS) as a patient report outcome measure (PROM) was included to assess satisfaction and improvement in oral health–related quality of life as a criteria for long-term analysis.[26] Finally, the establishment of in vitro, in vivo, and ex vivo studies focused on ceramic aging and the impact of debris at the cellular and tissue levels were also addressed.

Consensus Statement 1

Using BIC% to determine the vertical bone loss

Between an implant and the surrounding bone, BIC% quantifies the percentage of contact. It is important to note that BIC % can only be determined histologically. Differences in BIC% serve as a measure for vertical bone loss (VBL), which is an important criterion in assessing implant performance and peri-implant bone defects. To accurately control VBL, cone-beam computerized tomography (CBCT) should be utilized. Cross-sectional images obtained from CBCT demonstrate the high accuracy and reliability of inlinear bone measurements related to implant treatment.[19] As a standard, a 2-mm safety margin for adjacent anatomical structures should be considered when using 2-dimensional images. A voxel size of 0.3 to 0.4 mm is adequate to provide images of acceptable diagnostic quality for bone-implant-contact evaluation. The measurement accuracy and reliability depends on the patient's immobility during the examination, use of the same device to capture the image, and use of the same software for its analysis. Digital tools are preferred for linear image measurements. The effectiveness of CBCT in aiding in geometric bone measurements and in the diagnosis of peri-implant bone defects is influenced by factors such as bone wall thickness, defect size, artifacts, implant material, adjustment of acquisition parameters, and observer experience.

When the peri-implant buccal wall is greater than 0.5 mm, there is less discrepancy between radiological and histological assessments.[27]

The axial reconstructions of the implants' CBCT images have been observed to exhibit beam-hardening artifacts. These artifacts appear as dark zones near the high density of the implant, which can hinder the visualization of the implant-bone interface or lead to an overestimation in the size of the digitized object.

Modern CBCT scanners utilize beam-hardening filters and adjust technical acquisition parameters to control image quality and reduce artifacts. These adjustments, such as mA and kVp settings, directly affect the ability to detect minor deficiencies in the implant area.[27] Additionally, metal artifact reduction algorithms utilizing iterative reconstruction to limit beam-hardening artifacts are available. Compared with titanium implants, zirconia implants show a greater underestimation of peri-implant defects with an average error of -1.28 mm.[28]

The intersection between the long-axis line of the implant and the mesiodistal line bounded by the most crestal bone seen at each side of the implant defines the bone level and is the value used to measure VBL in subsequent consultations (Figure 1).

The values were assessed at specific time points as follows: T(0), immediately after implant placement; T(1), 6 months after implant placement; T(2), 12 months after implant placement; and T(3), 3 years after implant placement in a randomized clinical trial (RCT).[8,10] If the insertion of the final restoration does not coincide with any of the mentioned time points, a new time corresponding to the moment of insertion of the definitive restoration should be considered. The clinical relevance lies in a standardized analysis for the clinician to measure

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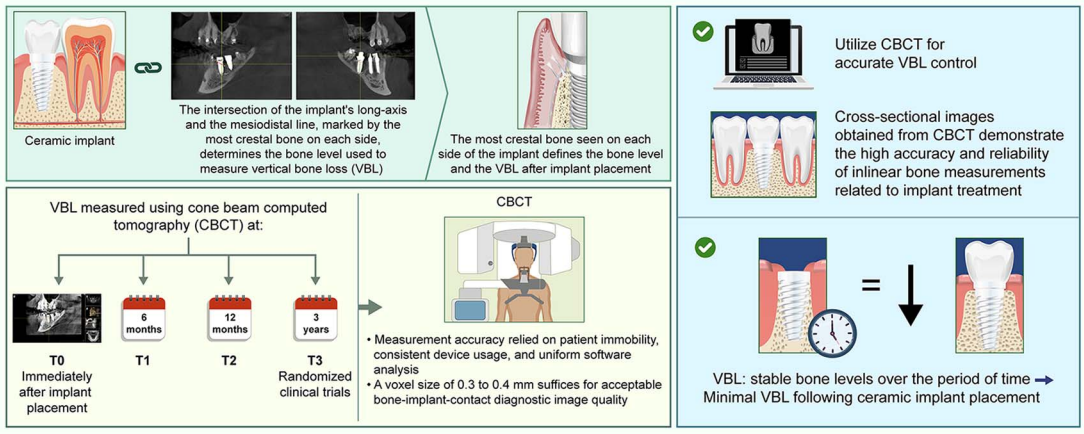

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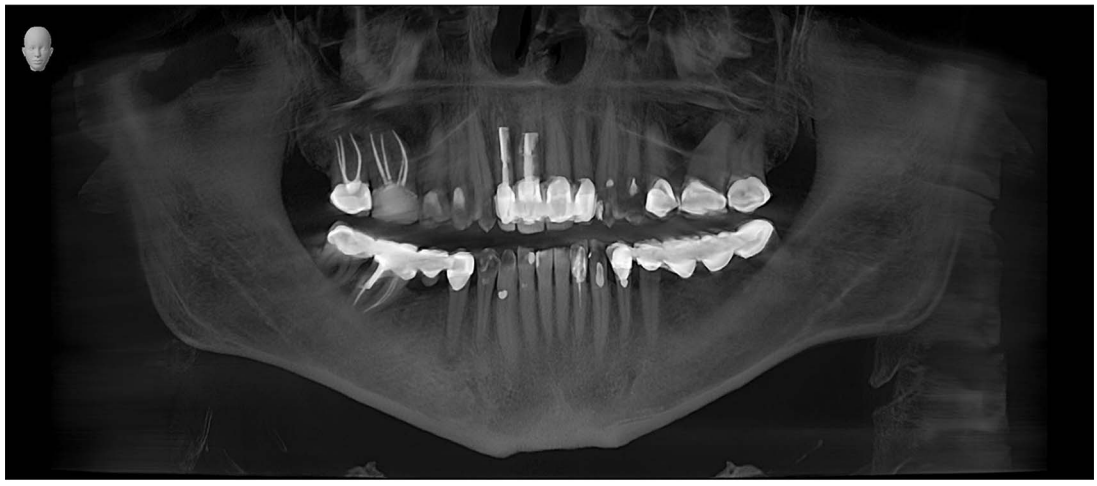

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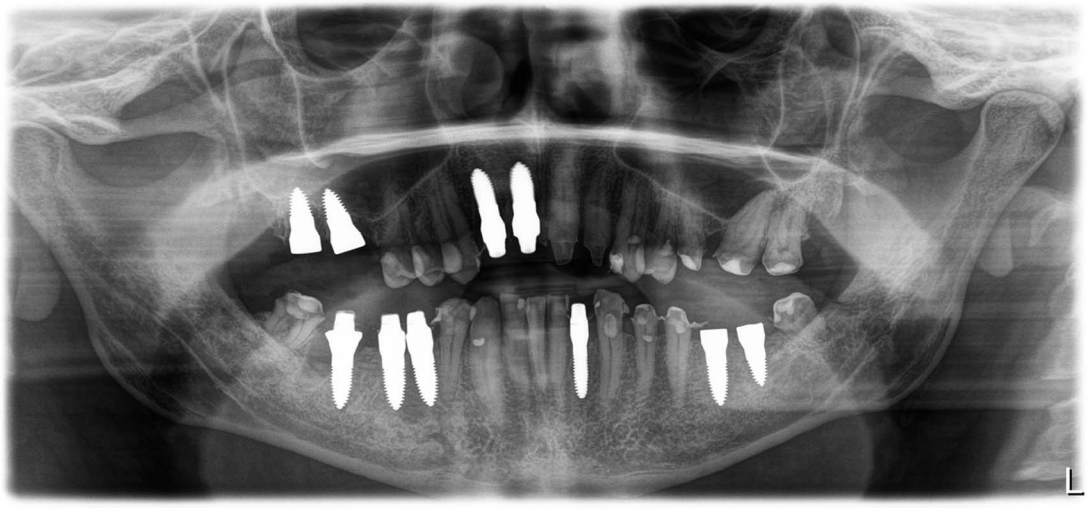

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Figure 1. Vertical bone loss (VBL) measurement on cone-beam computerized tomography cross-sectional longitudinal images. (a) VBL measurement. (b) Orthopantomographic with initial situation. (c) Orthopantomographic T0 image immediately after implantation. (d) VBL T0 image after late implantation of 1-piece ceramic implant placed at first molar lower jaw region. (e) Image (d) with high contrast. (f) VBL T2 (12 months after implantation) image of 1-piece ceramic implant with subsequent pillar cementation and crown. (g) Image (f) VBL with high contrast. (h) Region of first molar lower jaw before implantation. (i) T0 VBL image immediately after implantation of 1-piece ceramic implant. (j) Image (i) with high contrast. (k) T2 (12 months after implantation) VBL image of 1-piece ceramic implant with crown. (l) Image (k) with high contrast.

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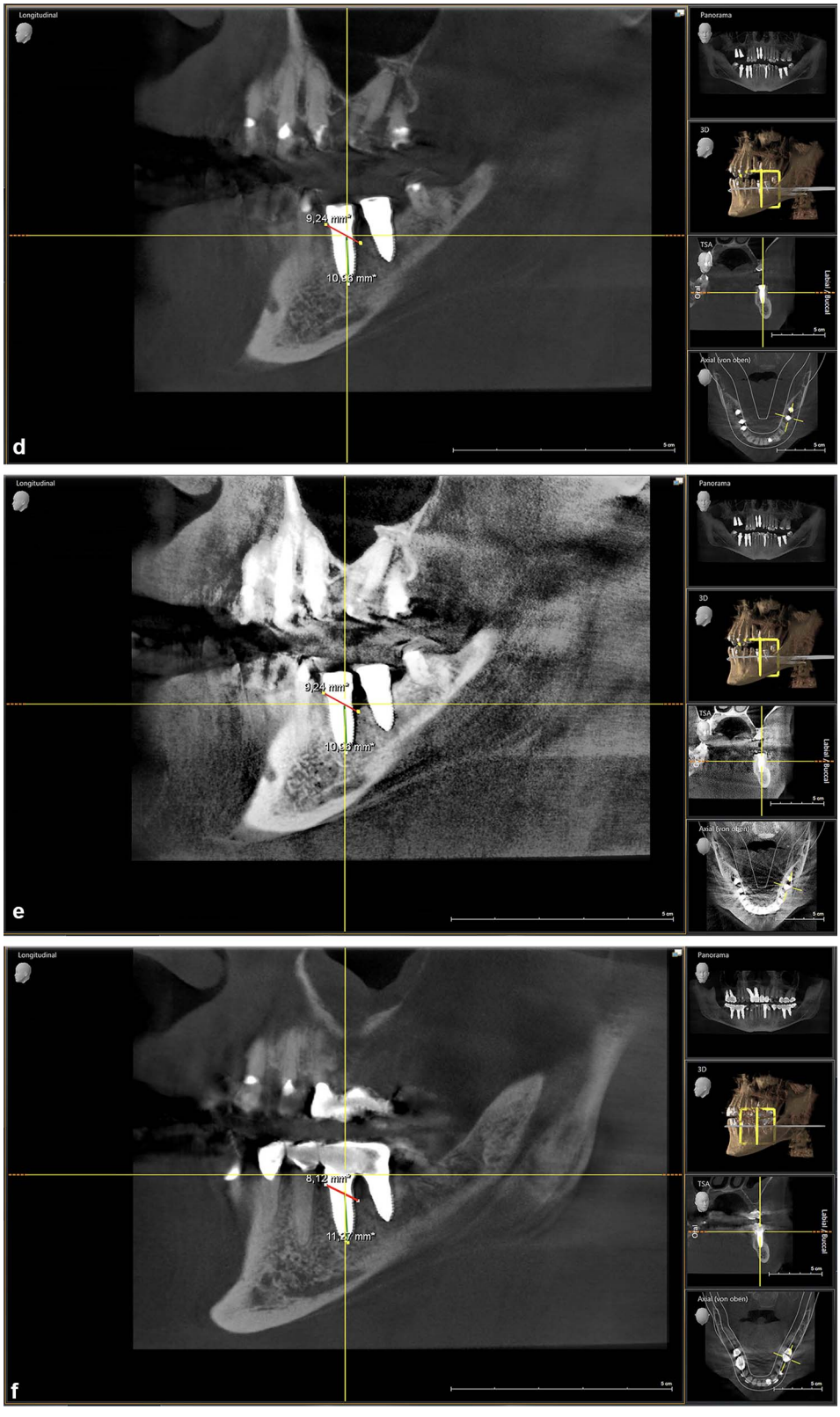

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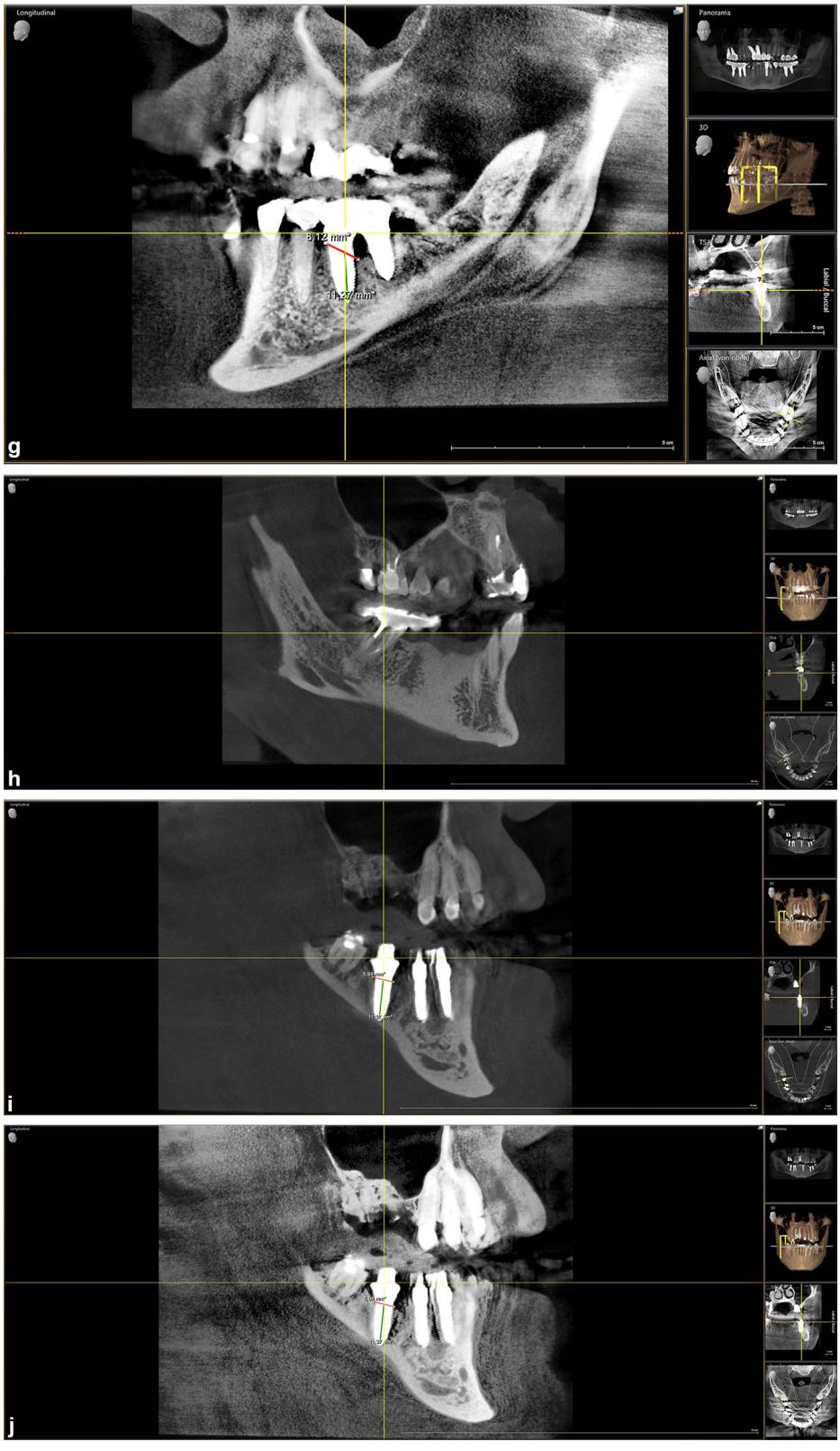

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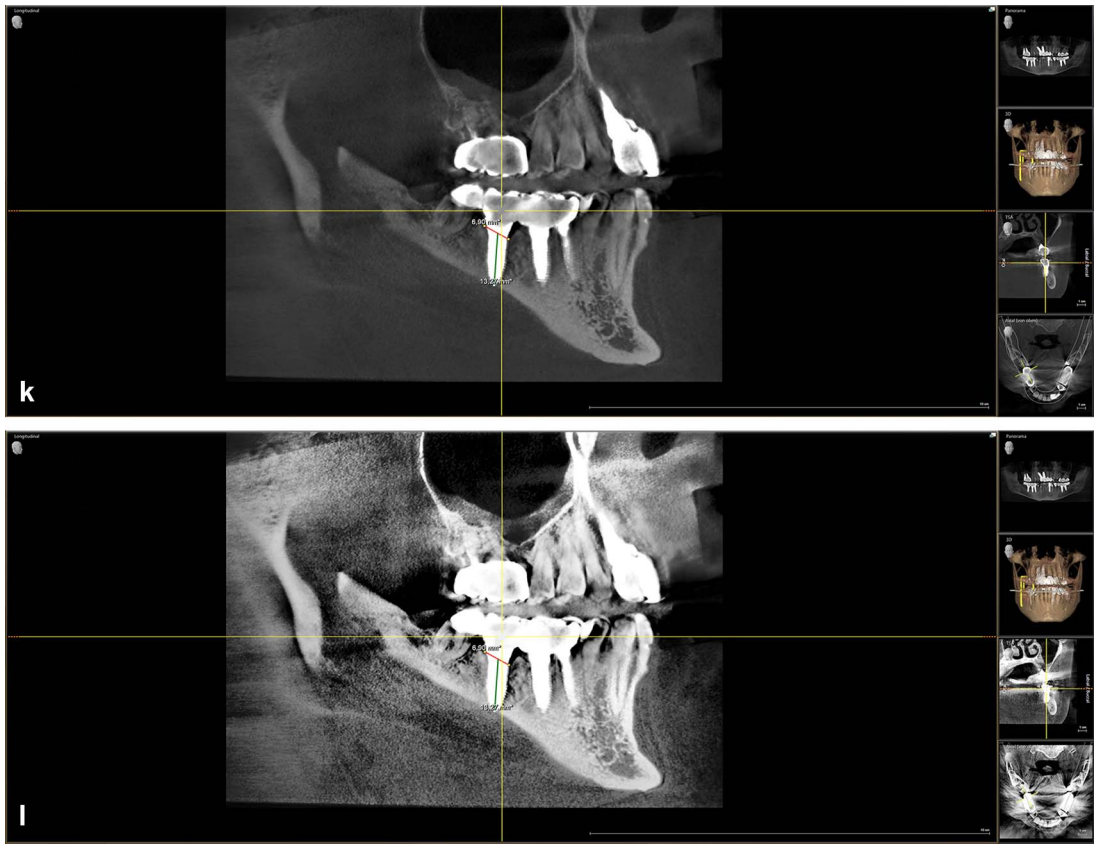

Figure 1 CONTINUED.

intergroup and intragroup differences comparatively and reveal significant VBL throughout the observation period. Analysis of stability and marginal bone regeneration is possible even when implant placement is performed with bone augmentation. Inaccurate measurements determined from the mean marginal bone loss were avoided. Thus, the digital images considered the aspect of the implant with the highest loss (mesial or distal).[29]

The VBL assessment and BIC% defined here are reliable and reproducible measurements and can be reported as clinical outcomes. Bone regeneration on the implant surface was considered a prerequisite for the long-term success of ceramic implant–supported prostheses, emphasizing the importance of osseointegration and stabilization of ceramic implants.

Preclinical studies

In vivo animal studies contribute to understanding bone and soft tissue healing around ceramic implants. Osseointegration, bone density, and cell description should be evaluated using histopathological and histomorphological approaches.[30]

Bone area fraction occupancy (BAFO) is the percentage of the area within the implant threads occupied by a visibly distinct mineralized bone matrix. The BIC% at the histological level and BAFO after 4, 8, and 12 weeks of implant placement define the circumferential bone deposition around the implant. Despite the limited relationship with VBL or the level of marginal bone, these are the preferred measurements for reporting biological results.[31,32]

Therefore, in vivo analyses should be performed in dogs. Small animal studies should consider in vivo microcomputerized tomography to provide morphological, functional, and perfusion information about the bone after implant placement.

Consensus Statement 2

Long-term mucosal stability and esthetic results can be achieved with immediate implant placement.[33,34] The lack of predictability of PES,[35] mucosal recession, and socket atrophy can be reduced by applying a minimally invasive surgical protocol that considers the anatomy and physiology of tooth-supporting tissues. This includes performing a flapless procedure, avoiding damage to the periosteum, and employing minimally invasive extraction techniques to preserve the lamellar bone.[36] The socket must be thoroughly cleaned, and other disinfection methods, such as ozone or antimicrobial photodynamic therapy, can also be applied. The ceramic implant system of choice should allow the drilling and insertion of implants without compressing the cortical or apical bone. Priority should be given to achieving stability first and enabling sufficient blood and cell perfusion for osseointegration without signs of scarring or fibrosis.[37]

Transmucosal components of implant systems should enhance soft tissue integration and peri-implant disease

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Table

The pink esthetic score and variables

	Mesial Papilla	Distal Papilla	Soft Tissue Contour	Height Of Marginal Gingiva	Alveolar Processes	Soft Tissue Color	Soft Tissue Texture
	2 complete 1 incomplete 0 missing	2 complete 1 incomplete 0 missing	2 natural 1 quite natural 0 unnatural	2 no discrepancy 1 low discrepancy 0 main discrepancy	2 no discrepancy 1 low discrepancy 0 main discrepancy	2 evident changes 1 minor changes 0 no changes	2 evident changes 1 minor changes 0 no changes
T0 Tooth/area							
T1 (7-10 days)							
T2 (6 months)							
T3 (1 year)							
T4 (3 years)							

management.[38] The abutments of bone-level implants with external connections may experience micromovements, resulting in screw loosening and bacterial microleakage. Abutments with internal connections, such as platform switching, mitigate this issue by reducing abutment diameter, which allows more space for peri-implant soft tissue and helps maintain marginal bone levels.[39] An internal abutment configuration with an angle of less than 45° and tissue-level implant designs have better prognoses on marginal bone loss.[40]

Tissue-level implants feature a fused convergent collar at or above the mucosa, eliminating the implant-abutment interface, microgaps, micromovements, or frequent reconnections needed during the prosthetic phase.[41] This design helps prevent dimensional changes in peri-implant tissues and the apical migration of mucosal barrier connective tissue. Further, tissue-level ceramic implants with a transmucosal polished whitish neck and supragingival healing reduce the potential for esthetic compromise of thin mucosal profiles during biological width establishment.[42]

The peri-implant region, consisting of alveolar bone and mucosa, lacks the cementum and periodontal ligament found around natural teeth. This presents challenges in managing the onset of peri-implant diseases, such as mucositis and peri-implantitis.[43] Therefore, preventive measures must ensure adequate oral hygiene and maintenance access, a disadvantage normally associated with the implant-abutment interface in bone-level implant designs.[44]

PES as a clinical outcome immediately after implant placement

The PES should be evaluated using digital photographic documentation with a digital, single-lens reflex camera adapted with a macrolens and flash ring system.[22] Photographs should be taken at specific time points: T(0), before treatment; T(1), immediately after implant placement and prosthesis delivery; T(2), 6 months after implant placement; T(3), 12 months after implant placement; and T(4), 3 years after implant placement, particularly in the context of RCTs. The images should be transferred to software and printed in color for evaluation. Six independent dentists, in addition to the study team, should evaluate the PES.[7]

Seven variables are evaluated using scores ranging from 0 to 2 points: mesial and distal papillae, soft tissue contour, marginal gingival height, alveolar process, soft tissue color, and soft tissue texture (Table).

Clinical trials

Long-term clinical results are defined as those obtained at least 5 years after loading the implant and restoring occlusion function. Controlled clinical studies are needed to assess tissue regeneration, osseointegration, and reconstruction of occlusal function concerning bone quality in larger patient cohorts.

Clinical studies should focus on wound management and understanding the healing process around implants. The re-epithelialization and formation of keratinized mucosa are essential to ensure sufficient vascular and cellular support using blood matrices, such as platelet-rich fibrin. Additionally, activating the patient's immune system by providing vitamins and nutritional supplements and applying minimally invasive and atraumatic surgical protocols can contribute to favorable outcomes.

Immediate implantation protocols may improve the patients' quality of life with fewer consultations, surgical exposures, and costs as well as quicker return to their professional and personal routines.[45]

Consensus Statement 3

Definition of 1- and 2-piece ceramic implants

The DGI undertook the task of redefining the guidelines for ceramic implants in 2022, acknowledging the distinctions between 1- and 2-piece ceramic implant systems and their indications and success rates.[25]

One-piece ceramic implants currently on the market demonstrate positive success and survival rates in scientific studies with long-term survival observed for periods of up to 7 years. They are viable and readily accessible treatment options when restored with single crowns and supported bridge restorations. The prosthetic procedure for a 1-piece implant is nearly identical to that for natural teeth.

One-piece ceramic implants consist of an implant body that is inseparably connected to the transmucosal component. The coronal part resembles the postabutment restoration platform, ensuring supragingival healing. This design eliminates the implant-abutment interface, thus avoiding microgaps and bacterial leakage. During the prosthetic restoration phase, this implant design may later receive a pillar on top that can be either cemented or screwed into place. One-piece implant systems are placed at the tissue level.[24,25]

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Two-piece ceramic implants facilitate subgingival healing. Subsequent adaptation of the transmucosal components and abutments allows for flexibility in the placement of the surgical implant aligned with the prosthetic axis. The 2-piece design, which is more recently available commercially, has limited evidence to conclusively assess its long-term clinical benefits compared with titanium implants. This highlights the importance of providing patients with comprehensive information on 2-piece ceramic implant therapy, considering long-term data, particularly regarding the stability of the prosthetic connection. Two-piece systems are placed at the bone level.[24,25]

Consensus Statement 4

PROM: VAS

PROMs for immediate implantation should follow the definitions outlined in the Group 3 International Team for Implantology Consensus Report.[8,46] Clinicians should assess patient perceptions of their psychosocial state, functional limitations, pain, discomfort, and expectations before implant treatment. Therefore, clinicians are advised to use PROMs when assessing clinical outcomes.

Before initiating implant treatment, it is essential to establish a baseline assessment of the patient's perception of oral health–related quality of life and satisfaction. A VAS has been adapted primarily to reduce the application time to a maximum of 5 minutes without compromising the beneficial objectives and accuracy of the data collected (Figure 2).

It is essential to compile multicenter VAS data as the biological properties of zirconia and advancements in technology will further expand the indications of ceramic implants in the future.

To conduct comparative analyses with titanium implants, PROMs for ceramic implant treatments should be comprehensive. Access to patient perception should be complete in cases of total, partial, and single-tooth rehabilitation. To achieve this goal, the VAS questionnaire should include questions about esthetics, pain, and social limitations before and after implantation.

Consensus Statement 5

Implant cleanliness, shape of ceramic implant debris, and the impact of heat during the drilling process

The potential role of contaminants arising from manufacturing, handling, and packaging in developing early peri-implantitis, bone loss, osseointegration failure, and soft tissue degradation is yet to be identified as a significant factor.

Patient-related factors are assumed to account for approximately 50% of the variability in the wear of ceramic implant–supported crowns or prostheses.[19] However, studies investigating the origin, particle size distribution, and morphology of the particles present in peri-implant tissues and in vivo studies using animal models, particularly in comparison with particles from titanium implants, are lacking.[47]

The following steps are suggested: (1) Qualitative examination of samples using a scanning electron microscope (SEM). According to the Deutsches Institut fur Normung (German Institute for Standardisation) (DIN) International Standardization Organization (ISO) Standard 22309, energy-dispersive X-ray spectroscopy can be used to assess the elemental composition of materials on damaged surfaces. Additional secondary ion mass spectrometry analyses can also be applied. This method provides information on the atomic and molecular structures of the uppermost monolayers of a sample on an analysis area of $500 \times 500\ \mu m^2$ with sensitivities down to the parts per million range and a lateral resolution of up to 100 nm. A comparison of the spectra with known substances enables precise material determination of the respective contamination. (2) Implant cleanliness can be evaluated in laboratories accredited according to DIN Europaische Norm ISO/International Electrotechnical Commission standard 17025:2018 following an established protocol of analysis.[47,48] (3) The generation of heat during the drilling process and its impact on cell behavior can be investigated using primary gingival fibroblast cells. Complementary analyses can be performed to assess cell morphology after 48 hours and microbial biofilm formation using an SEM.

Conclusion

Ceramic implants are part of an evolutionary period in the extensive knowledge of oral biological systems and address the growing concerns regarding titanium hypersensitivity reactions associated with endosseous dental implants and increasing esthetic demands. There exists ample clinical evidence supporting the long-term survival and efficacy of 1-piece ceramic implants. These implants are designed to foster supragingival healing, promote soft tissue adherence, and offer improved management of peri-implant diseases. The stability of soft tissue surrounding ceramic implants mirrors their biocompatibility.

Assessing VBL and the PES along with their timing for evaluation are reliable metrics for monitoring peri-implant tissue health and implant performance. These measurements are crucial tools for decision making in effectively managing the advancement of mucositis or peri-implantitis. Additionally, implementing the VAS as a PROM can ensure swift and practical routine assessments, incorporating patients' quality of life in postimplant therapy.

The precise positioning of 1-piece ceramic implants is pivotal for achieving optimal prosthetic function and restoration. Because of the absence of an implant-abutment interface, 1-piece ceramic implants offer significant advantages in terms of maintenance and accessibility. However, despite the bone-level ceramic implants demonstrating promising outcomes, their limited availability in the market impedes the accumulation of sufficient long-term clinical evidence. This finding underscores the need for further research in this domain.

This consensus underscores the need to prioritize studies that aim to prevent implant-related diseases in the supporting tissues and investigate the short- and long-term responses of soft tissues surrounding the implant. Considering the multidisciplinary nature and etiology of peri-implant diseases discussed in the concluding remarks, further studies are, therefore, necessary.

Abbreviations

BIC%: bone-implant-contact percentage
PES: pink esthetic score
DGI: German Association of Oral Implantology

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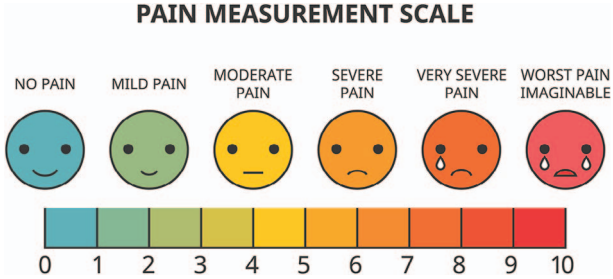

Functional Limitation	**VAS (0-10)**
Do you have trouble pronouncing any word because of problems with your teeth, implants, mouth or dentures?	
Do you felt that your sense of taste has worsened because of problems with your teeth, implants, mouth, or dentures?	
Have you been limited in your chewing function by your dental problems?	
Do you grind your teeth at night or wake up with a locking jaw and headache?	
Psychological Discomfort	
Do you feel insecure because of problems with your oral cavity?	
Do you avoid laughing and showing your teeth?	
Do you feel insecure with your teeth?	
Are you satisfied with your dental aesthetics?	
Physical Pain	
Do you have pain / sore spots in your oral cavity?	
Do you have sore spots in your oral cavity?	
Are you limited in your daily activities due to the pain?	
Are you limited in your social interactions due to the pain?	
Do you have pain at TMJ (jaw join)?	
Which side? Right?	
Which side? Left?	
Physical Disability	
Do you have trouble eating because of your teeth, implants, mouth or dentures?	
Where? Above?	
Where? Below?	
Where? Right?	
Where? Left?	
Social Disability	
Are you able to meet your personal obligations and socialize?	
Are you limited in your social interactions because of your teeth?	
Handicap	
Do you feel that your quality of life is affected because of problems with your teeth, implants, mouth or dentures?	

Figure 2. The visual analog scale is designed to be applied in 5 minutes. (a) Pain measurement scale to assess the patient's perception before and after treatment with a scale ranging from 0 to 10. (b) Comprehensive questions designed for treatments involving the implantation of ceramic implants.

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VAS: visual analog scale
PROM: patient report outcome measure
VBL: vertical bone loss
CBCT: cone-beam computerized tomography
RCT: randomized clinical trial
BAFO: bone area fraction occupancy
SEM: scanning electron microscope

Acknowledgments

This document was written on behalf of the Ceramics & Biological Dentistry Foundation and the Society for Blood Concentrates and Biomaterials. We thank the members of the American Academy of Implant Dentistry, the German Association for Oral Implantology, and the Academy of Osseointegration for enabling discussions and support.

Note

The authors have no conflicts of interest to declare. All coauthors have seen and agree with the manuscript, and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

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