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Impact of Custom-Designed vs. Standard Titanium Healing Abutments on Peri-Implant Tissue Health in Immediate Post-Extraction Implant Sites: A Systematic Review

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ABSTRACT

This systematic review dives into the effectiveness of custom-designed healing abutments compared to standard titanium ones in helping the tissues around dental implants heal, especially when implants are placed right after a tooth is pulled. We searched major medical databases like PubMed and Cochrane up to May 2025 for studies that directly compared these two types of abutments in people. Our aim was to see how they influenced soft tissue changes, bone stability, esthetic outcomes, and even germ responses. What we found suggests that custom-made abutments tend to lead to better soft tissue results, including more stable tissue dimensions and a more natural-looking gum line. This seems to be because they're designed to perfectly guide the healing tissues, mimicking the original tooth's shape. While both types of abutments appear equally good for the implant to fuse with the bone, there wasn't a consistent, clear difference in how much bone was lost around the implant. Information on how these abutments affect bacteria was also quite limited. Despite the promising esthetic and soft tissue benefits, it's important to remember that the studies we looked at varied a lot in how they were done, which means we couldn't combine their data statistically. For clearer answers, future research really needs well-designed studies that follow consistent rules and track patients for longer periods.

Keywords: Immediate implant, Fresh extraction socket, Healing abutment, Customized abutment, Titanium abutment, Peri-implant tissue, Esthetics, Systematic review

INTRODUCTION

In the world of dental implants, placing an implant right after a tooth extraction has become a really popular and often predictable way to go. This approach, known as immediate implant placement, offers some fantastic perks compared to waiting around, especially when we're talking about teeth that show when you smile [1, 5]. By doing things in one go, we can cut down on the total treatment time, avoid extra surgeries, and hopefully make the whole experience less stressful and more comfortable for patients. What's more, it gives us a golden opportunity to save the natural jawbone and the surrounding gum tissues, which otherwise tend to shrink and change shape quite a bit after a tooth is removed [1, 3, 4]. Keeping these natural structures intact is super important for achieving a beautiful smile and making sure the implant stays healthy and stable for years to come [4].

But here’s the thing: a successful immediate implant isn't just about the implant itself securely attaching to the bone. A huge part of long-term success, especially if we want that perfect smile, is making sure the gum tissues around the implant are healthy, stable, and beautifully shaped. These soft tissues, which include the gingiva (gums) and the connective tissue underneath, form a vital seal around the implant. This seal acts like a protective barrier, keeping bacteria away from the bone and playing a big role in how natural the implant-supported tooth looks [4]. The real trick is to guide the healing process so that the new tooth appears to emerge seamlessly from the gums, just like a natural tooth would.

This is where healing abutments step in. Think of them as temporary guides that help shape the gum tissue during the initial healing phase. Traditionally, dentists have used standard titanium healing abutments. These are usually cylindrical or slightly cone-shaped. While they do a good job of creating a pathway through the gum for the implant and helping it integrate with the bone, their generic design might not always perfectly support the delicate and unique shape of a fresh extraction socket [6]. This can sometimes lead to less-than-ideal esthetic results, like not enough gum tissue volume, receding

gums, or those annoying "black triangles" between teeth, ultimately leaving patients unhappy with how their smile looks [6]. The mismatch between a standard abutment's general shape and the specific contours of the socket can actually prevent the gum tissue from developing its best, most natural-looking profile.

To tackle these limitations, the idea of customized healing abutments has really taken off. These clever abutments are often made using advanced digital techniques, like Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) [16, 17, 18]. The core principle behind customized healing abutments is their ability to precisely mirror the natural root shape and the original gum line of the tooth that was just pulled. By replicating these unique anatomical features, these custom-designed abutments are meant to give superior support and guidance to the healing gum tissues. The goal is to encourage a more anatomically accurate and stable gum seal around the implant [16, 17, 18, 21]. This personalized approach aims to create the best possible gum architecture, leading to a more natural and esthetically pleasing outcome that blends perfectly with the surrounding teeth [21].

The proposed benefits of customized healing abutments are pretty exciting: better preservation of the gum margin, improved support for the papilla (the little triangle of gum between teeth), less gum recession, and optimized gum tissue thickness. All of these are absolutely vital for achieving top-notch esthetic results [6, 7, 21]. Several clinical studies have looked into how customized healing abutments affect various gum tissue measurements and esthetic outcomes, and some early evidence does point to advantages over traditional titanium abutments [8, 9, 10, 11, 12]. However, the existing research can sometimes be a bit mixed or even contradictory, which really highlights the need for a thorough and systematic look at all the available evidence. A comprehensive systematic review is crucial to bring together what we know, identify consistent findings, and point out where we still need more research. This way, dentists can get clear, evidence-based guidance to make the best treatment decisions for immediate implant cases.

So, the main goal of this systematic review is to carefully evaluate and compare how custom-designed healing abutments stack up against standard titanium healing abutments in terms of peri-implant tissue health. This evaluation covers a range of important aspects, including changes in both the soft tissue (like gum height, thickness, and overall volume stability) and the underlying bone (such as changes in bone levels around the implant), as well as overall esthetic results and, if reported, how these abutments affect bacteria. By systematically reviewing the current evidence, we hope to gain a clearer understanding of how effective customized healing abutments are in improving the long-term success of immediate implant placement into fresh extraction sockets.

Methods

Focused Question

We designed this systematic review very carefully to answer a specific clinical question, using a framework called PICO (Population, Intervention, Comparison, Outcome). This structured approach helps us keep our review clear, comprehensive, and focused, guiding our search for relevant studies.

- **P (Population):** Our review focuses on human patients who have had a dental implant placed immediately after a tooth was extracted. This specific focus ensures that the studies we include are directly relevant to this particular clinical situation, considering the unique way tissues heal in these immediate post-extraction sites.
- **I (Intervention):** The treatment we're interested in is the use of custom-designed healing abutments. This includes abutments made using various personalized techniques, most commonly CAD/CAM technologies. These are specifically shaped to mimic the natural tooth's emergence profile and provide tailored support to the healing gum tissues.
- **C (Comparison):** We're comparing this intervention against the use of standard, off-the-shelf titanium healing abutments. These are the more traditional options, usually cylindrical or conical, that create a pathway through the gum during the initial healing period.
- **O (Outcome):** The main things we're looking at are related to how the tissues around the implant heal. This broad category includes several specific measurements:
    - **Soft Tissue Dimensional Changes:** This involves measuring things like gum height (whether it

recedes or moves up), gum tissue thickness, and overall volume changes of the gum around the implant. These objective measurements are key indicators of how good the esthetic result is and how stable the tissue remains.

- **Bone Stability:** Here, we're looking at changes in the bone levels around the implant, typically measured from X-rays or other imaging scans. Keeping the bone around the implant healthy is crucial for the implant to last a long time and for good esthetics.
- **Esthetic Outcomes:** This covers both objective ways of assessing beauty (like using scores such as the Pink Esthetic Score or White Esthetic Score) and what patients themselves think about how their smile looks.
- **Microbiological Responses:** If studies reported on this, we're looking at things like how bacteria colonize the abutment, how biofilms form, and any signs of inflammation around the healing abutments. This gives us clues about how well the materials are tolerated by the body and any potential long-term health implications.

Search Strategy

To find all the relevant studies, we conducted a thorough and systematic electronic search across the major biomedical and dental literature databases. We made sure to search up to the end of May 2025 to include the very latest evidence. We systematically queried the following databases:

- **PubMed/MEDLINE:** A go-to database for medical literature.
- **Scopus:** A large database that includes abstracts and citations from peer-reviewed research.
- **Web of Science:** A platform that covers scientific research from many different fields.
- **Cochrane Library:** A collection of databases known for providing high-quality, independent evidence to help inform healthcare decisions, including systematic reviews and controlled trial registers.

For each database, we carefully put together our search strategy using a mix of specific medical terms (MeSH terms) and general keywords. We used Boolean operators (like "AND" and "OR") to make our searches broader or more specific as needed. The keywords were directly taken from our PICO question to make sure we found as many relevant studies as possible without getting too many irrelevant ones. Some examples of the search terms we used included:

- "immediate implant" OR "immediate placement" OR "immediate loading"
- "fresh extraction socket" OR "post-extraction socket" OR "extraction site"
- "healing abutment" OR "healing cap" OR "gingival former"
- "customized abutment" OR "custom healing abutment" OR "CAD/CAM abutment" OR "individualized abutment"
- "titanium abutment" OR "conventional abutment" OR "standard abutment"
- "peri-implant tissue healing" OR "soft tissue healing" OR "bone healing" OR "gingival recession" OR "esthetic outcome" OR "marginal bone loss"

We limited our search to human studies published in English. This was mainly for practical reasons, as translating studies from other languages would have been very time-consuming, and most high-quality research tends to be published in English. To catch any studies that our electronic search might have missed, we also meticulously hand-searched the reference lists of all the systematic reviews and highly relevant primary studies we found. This step-by-step process helped us ensure we didn't overlook any important literature.

Inclusion and Exclusion Criteria

We set up very strict rules, called inclusion and exclusion criteria, right from the start. This was to make sure that only studies directly addressing our main question and meeting high quality standards were included in our review.

Inclusion Criteria:

- **Study Design:** We only considered randomized controlled trials (RCTs), prospective cohort studies, and retrospective studies. RCTs are considered the gold standard because they're designed to minimize bias, but we also included prospective and retrospective cohort studies to get a broader picture, especially since this area of dentistry is

always evolving. We specifically left out case reports, case series, and general review articles because they don't provide enough reliable evidence for drawing strong conclusions.

- **Participants:** Studies had to involve human patients who received an immediate dental implant into a fresh extraction socket. This ensured that our findings would be directly applicable to the clinical situation we're studying.
- **Intervention and Comparison:** It was essential that studies directly compared the use of customized healing abutments with standard titanium healing abutments. This direct comparison is at the heart of what our review aims to find out.
- **Outcome Measures:** Studies needed to report on at least one of the outcomes we defined (soft tissue changes, bone stability, esthetics, or microbiological responses). This ensured that the included studies provided data relevant to assessing the effectiveness of the abutments.
- **Follow-up Period:** We required a minimum follow-up period of 3 months. This duration is generally enough to see initial soft tissue healing and early bone changes, though we preferred studies with longer follow-ups for better long-term insights.
- **Language:** Only studies published in English were included, mainly due to the practical challenges of translating and reviewing studies in other languages.

Exclusion Criteria:

- **Study Design:** We excluded laboratory studies (in vitro), animal studies, and purely theoretical research, as their findings don't always translate directly to human patients.
- **Clinical Context:** Studies that didn't involve immediate implant placement (e.g., those looking at implants placed much later) or didn't specifically focus on fresh extraction sockets were excluded to keep our review very specific.
- **Abutment Type:** If a study didn't compare customized and standard healing abutments, or if it focused on other types of abutments (like temporary crowns or final abutments without a healing phase comparison), we didn't include it.
- **Data Availability:** Studies that didn't provide enough clear data for us to extract and analyze, or those that didn't report on any of our specified outcomes, were excluded.
- **Follow-up Period:** Studies with a follow-up period shorter than 3 months were excluded because they might not capture stable healing outcomes.

Data Extraction

To make sure our data was accurate and unbiased, two trained reviewers independently extracted data from each included study. We used a standard, pre-designed data extraction form to systematically collect all the important information. We even tested this form on a few articles first and fine-tuned it to make sure it was clear and covered everything we needed. The information we pulled out included, but wasn't limited to:

- **Study Details:** Who wrote it, when it was published, where it was from, what kind of study it was (RCT, prospective, retrospective), and any funding sources.
- **Patient Information:** How many patients and implants were involved, their age range, gender, and any relevant health conditions.
- **Implant Specifics:** The brand of implant, its size, surface treatment, and where it was placed (e.g., front upper jaw, back lower jaw).
- **Abutment Details:** Specifics about the customized healing abutment (like what it was made of, how it was made using CAD/CAM, and its design) and the standard titanium healing abutment (its shape and dimensions).
- **Surgical Procedure:** Details about how the tooth was extracted (e.g., gently), whether bone grafting was used, and how stable the implant was right after placement.
- **Outcome Measurements and How They Were Assessed:**
    - **Soft Tissue:** Measurements like the gum level at the front of the tooth, papilla height, width of the attached gum, and gum tissue thickness (e.g., measured with a probe, digital scans, or 3D X-rays).
    - **Bone:** Changes in bone levels around the implant (on the sides, front, and back) measured from X-rays (like small dental X-rays,

panoramic X-rays, or 3D X-rays) relative to a fixed point on the implant.

- **Esthetics:** Scores from validated esthetic scales (like the Pink Esthetic Score (PES) or White Esthetic Score (WES)) or what patients reported about their satisfaction with the appearance.
- **Microbiological:** How microbial samples were collected (e.g., with paper points or swabs), lab techniques used (like culturing or molecular tests), and identification of specific bacteria or inflammation markers.

- **Follow-up:** How long and how often patients were checked after the procedure.
- **Complications:** Any problems that occurred, such as infections, abutment breakage, or implant failure.

If the two independent reviewers disagreed on any piece of extracted data, they would discuss it thoroughly until they reached an agreement. If they still couldn't agree, a third, senior reviewer would step in to make the final decision, ensuring the extracted data was as reliable and valid as possible.

Risk of Bias Assessment

We carefully checked the quality of each included study and its potential for bias. This helped us understand how strong the evidence was. We used different tools depending on the type of study:

- **For Randomized Controlled Trials (RCTs):** We used the Cochrane Risk of Bias tool (version 2.0, or RoB 2) [13]. This is a very thorough tool that looks at five key areas of potential bias:
  1. **Bias from the randomization process:** Did they randomly assign patients fairly?
  2. **Bias from deviations from intended interventions:** Did patients actually stick to their assigned treatment, and were the researchers/patients aware of the treatment (blinding)?
  3. **Bias from missing outcome data:** Was there a lot of missing data, and was it handled properly?
  4. **Bias in measuring the outcome:** Were the people measuring the results unaware of which treatment patients received (blinding)? Were the measurements reliable?
  5. Bias in selecting the reported result: Did they only report the good results and hide the bad ones?

  We rated each area as "low risk," "some concerns," or "high risk," and then gave an overall risk of bias judgment for each study.
- **For Non-Randomized Studies (Prospective and Retrospective Cohort Studies):** We used the Newcastle-Ottawa Scale (NOS). This scale looks at three main aspects:
  1. **Selection:** How similar were the groups of patients at the beginning of the study?
  2. **Comparability:** Did they account for other factors that could influence the results?
  3. Outcome: How accurately were the results measured, and was the follow-up long enough? Studies earned stars (up to a maximum of nine) for meeting specific quality criteria, with more stars indicating a lower risk of bias.

Both reviewers independently assessed the risk of bias, and any disagreements were resolved through discussion or, if necessary, by consulting the third reviewer. The results from this bias assessment were crucial for our qualitative summary and for understanding how much we could trust the evidence for each outcome.

Data Synthesis

Because the studies we included were quite different in their designs, specific measurements, assessment methods, and how they reported their findings, we decided that a statistical meta-analysis wouldn't be appropriate. Instead, we performed a comprehensive qualitative synthesis of the findings. This approach allowed us to describe and critically evaluate the evidence, highlighting consistent patterns, any conflicting results, and areas where we still need more research.

Our qualitative synthesis involved:

- **Thematic Analysis:** We grouped studies based on the specific outcomes they reported (for example, all studies that looked at gum height, or all studies that looked at bone loss).
- **Descriptive Summary:** For each group, we provided a detailed story of what each included study found.

We noted the direction of the effects (e.g., did customized abutments lead to more or less gum recession?), whether the results were statistically significant, and any important clinical observations.

- **Identification of Trends:** We actively looked for consistent patterns or tendencies across multiple studies regarding how effective customized versus standard healing abutments were.
- **Assessment of Heterogeneity:** We discussed why the studies might be different (e.g., differences in patient groups, implant brands, abutment materials, follow-up times, and measurement techniques) and how these differences might affect how comparable the results were.
- **Interpretation in Context:** We interpreted our findings by considering the quality of each study and its potential for bias. Studies with higher quality were given more weight in our overall summary.

Throughout the entire process of writing this systematic review, we strictly followed the guidelines from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [14]. This ensured that our methods and findings were presented clearly, completely, and accurately.

Results

Study Selection

Our initial systematic search across PubMed, Scopus, Web of Science, and Cochrane Library brought up a total of 46 articles that seemed potentially relevant. After carefully going through them, we found and removed 21 duplicate records, leaving us with 25 unique articles to look at more closely. These 25 articles then went through an initial screening where we reviewed their titles and abstracts to see if they were relevant to our main question. During this step, we ended up excluding 20 articles for various reasons – some were just review articles, others were case reports, animal studies, or they simply didn't directly compare customized and standard healing abutments.

In the end, 5 articles were identified as potentially suitable and moved on to a full-text review. After a thorough examination of these full texts against our predefined inclusion and exclusion criteria, all 5 studies met our requirements and were ultimately included in the qualitative summary of this systematic review. We've illustrated this detailed process of how studies were identified, screened, and included, along with the reasons for exclusion at each stage, in a PRISMA flow diagram (just like the one in Figure 1 of the PDF you shared).

Characteristics of Included Studies

The 5 studies we included involved a combined total of 123 patients and 170 dental implants. The types of studies varied: we had one randomized controlled trial (RCT), two prospective cohort studies (where patients are followed forward in time), and two retrospective studies (looking back at patient records). The time patients were followed in these studies ranged from 6 months to 36 months, giving us insights into both short-term healing and how things held up over a medium period. Most of the studies focused on implants placed immediately in the front upper jaw, which is a really important area for how a smile looks. However, some studies also included back teeth, acknowledging that function and esthetics matter there too. The customized healing abutments used in these studies were mostly made using CAD/CAM technology, often from materials like poly(methyl methacrylate) (PMMA) or composite resins bonded to titanium bases, all designed to perfectly match the natural tooth's emergence profile. Standard titanium healing abutments were used as the comparison in all these studies.

Impact on Peri-Implant Soft Tissue Dimensions

Changes in the size and shape of the gum tissues around the implant were a common finding reported across the included studies. Generally, the trend pointed towards better outcomes when customized healing abutments were used.

- **Buccolingual Width and Volume:** Two studies mentioned that customized abutments were linked to a noticeable decrease in buccolingual width. This could mean the soft tissue was more precisely contoured towards the implant, or it might just reflect the initial size of the socket [8]. On the other hand, other studies, even without exact numbers for buccolingual width, emphasized how customized abutments helped maintain or even increase soft tissue volume, especially in cases where the bone was thin [9]. Fernandes et al. (2021) observed that when customized healing abutments were used

along with bone substitutes and collagen matrices, they could help reduce tissue erosion around the implant, suggesting they play a role in keeping soft tissue volume intact [9]. Another study also hinted that customized healing abutments might lead to greater volume changes when the bone is thin and could help close larger sockets, thereby preserving the socket's original volume [9].

- **Gingival Height and Recession:** Studies consistently showed that customized healing abutments did a better job of preserving the gum line on the cheek side and minimized gum recession compared to standard abutments [9, 12]. Choorak et al. (2021) specifically pointed out that customized healing abutments could maintain the structure and horizontal dimension of the tissue that goes through the gum, as well as the vertical height of the gum on the tongue side and the buccolingual width over a 6-month period. Their study also indicated that most of the significant gum tissue changes happened within the first month, after which the tissue dimensions stayed pretty consistent, except for the cheek side [8].
- **Emergence Profile:** The ability of CAD/CAM customized abutments to maintain the natural emergence profile was a recurring and important finding. This significantly contributed to better soft tissue support and a smoother, more harmonious transition from the implant to the final crown [11, 12]. This precise anatomical replication is a key reason why customized abutments are so effective in shaping the gum tissue.

Impact on Esthetic Outcomes

How good things looked esthetically was assessed in various ways, including objective scores and what patients themselves thought. The general consensus was that customized healing abutments led to superior esthetic results.

- **Gingival Contour and Papilla Fill:** Studies suggested that patients who received customized healing abutments often had more natural-looking gum contours and better fill in the papilla (the gum triangle between teeth) compared to those with standard titanium abutments [4, 7]. This is directly linked to the customized abutment's ability to perfectly shape the soft tissue to mimic the natural tooth's emergence profile [6, 7, 16, 17, 18, 21].
- **Overall Esthetic Scores:** While specific esthetic scores (like the Pink Esthetic Score) weren't always consistently reported with direct statistical comparisons between the two groups in every study, the overall qualitative assessment indicated that the tailored soft tissue support from customized abutments led to higher overall esthetic satisfaction and more natural-looking results [4, 7]. The importance of excellent soft tissue management, which customized abutments help facilitate, was clearly reinforced as crucial for achieving esthetic success in implant dentistry [4].

Impact on Bone Stability and Osseointegration

We also looked at how healing abutments influenced the stability of the bone around the implant and how well the implant fused with the bone.

- **Osseointegration Rates:** All the studies we included reported very high implant survival rates (close to 100% in studies with longer follow-ups, like 36 months). This tells us that the type of healing abutment, whether customized or standard, didn't negatively affect the fundamental process of osseointegration (the implant fusing with the bone) or the implant's overall stability [11, 12, 19, 20].
- **Marginal Bone Loss:** While some studies hinted that customized abutments might offer some protection for the bone levels around the implant due to a better gum seal, we didn't consistently find direct and statistically significant differences in bone loss between the two abutment types across all the studies. For example, Hu et al. (2018) reported similar amounts of bone loss on both the cheek and tongue sides between the two groups, with comparable changes in bone thickness on the cheek side [10]. Menchini-Fabris et al. (2020) did suggest that the customized group had a significantly smaller decrease in bone width compared to the conventional group over 36 months, which indicates a benefit in bone preservation [11]. Giovanni-Battista et al. (2019) also noted that while bone width decreased in both groups, the change in the customized group was not significant compared to the standard group, and they saw a notable difference based on tooth type, with front teeth showing less bone loss [12]. The complex mix of

factors that influence bone remodeling around immediate implants – like how stable the implant is initially, how any gaps between the implant and socket wall are managed, the implant's surface characteristics, and whether bone grafting materials are used – might explain why the findings varied [19, 20].

Microbiological and Cytological Responses

Information specifically comparing how customized versus standard titanium healing abutments affect bacteria and cell responses in immediate implant sites was quite limited in the studies we reviewed. One relevant study by Al-Wattar et al. (2017) gave some general insights into how healing abutments influence bacteria and cells, pointing out that the material and surface of the abutment can affect how bacteria colonize and how the body's tissues react [15]. Since customized abutments can be made from different materials (like PMMA or composite resins) bonded to titanium, their long-term impact on bacteria compared to pure titanium surfaces really needs more dedicated research, especially in the context of immediate implant placement. The possibility that different materials might attract different bacterial biofilms is a crucial point for the long-term health of the tissues around the implant.

Discussion

This systematic review set out to bring together all the current scientific evidence on how custom-designed healing abutments compare to standard titanium ones in helping the tissues around dental implants heal, particularly when implants are placed right after a tooth is pulled. What we've gathered suggests a clear trend: when customized healing abutments are used, we tend to see better outcomes for the soft tissues, especially in terms of how stable their dimensions are and how nicely they shape up esthetically. This section will dive deeper into what these findings mean, their practical implications for dentists, acknowledge the limitations of the current research, and suggest where future studies should focus.

Interpretation of Findings

The reason customized healing abutments seem to do such a great job shaping the gum tissues around implants largely comes down to their unique design philosophy: they're made to perfectly match the natural emergence profile of the original tooth. Unlike generic, off-the-shelf abutments, custom-designed ones are precisely tailored to the individual patient's extraction socket and the desired final shape of the new tooth [6, 16, 17, 18, 21]. This "scaffolding" effect provides immediate and continuous support to the healing gum tissues. It guides them as they mature and prevents the gum architecture from collapsing, which can happen with less perfectly fitting conventional abutments.

This precise guidance is incredibly important for a few key reasons. First, it helps keep the volume of gum tissue on the cheek side, which is very prone to shrinking and receding after a tooth is extracted, especially in the visible part of your smile [3]. By offering a stable template, customized abutments can minimize how much the gum line moves down and preserve the natural curve of the gum, thereby reducing the chances of esthetic problems like "black triangles" or seeing parts of the implant. Second, the natural harmony created by these abutments significantly contributes to how well the implant restoration blends in esthetically. It allows the final crown to emerge gracefully from the gums, looking just like a healthy natural tooth [21]. The idea of "sealing socket abutments" further highlights how important these custom components are in achieving a primary seal over the extraction socket. This seal can protect the blood clot, stabilize any bone graft material used, and promote undisturbed healing of the bone and soft tissues underneath [17]. This seal might also help keep bacteria from getting into the healing socket, potentially leading to a healthier healing environment.

While the benefits for gum tissue esthetics and stability look promising and are backed by several studies [8, 9, 12], the evidence for significant differences in bone stability around the implant between the two abutment types wasn't as consistent across all the studies we looked at. This might be because many factors influence how bone remodels around immediate implants. Things like the initial amount of bone, how any gaps between the implant and the socket wall are handled, the implant's initial stability, the characteristics of the implant surface, and whether bone grafting materials are used all play a big role in affecting bone level changes [19, 20]. So, while customized abutments might help create a healthier gum seal, their direct impact on bone preservation might be less noticeable compared to these other powerful factors. The consistently high rates of osseointegration (the implant fusing with the bone) reported for both types of abutments suggest that the choice of healing

abutment mainly affects the gum tissue and the esthetic outcome, rather than the fundamental biological connection of the implant to the bone.

The limited data on how these abutments affect bacteria and cells points to a significant gap in our current knowledge. The materials and surface characteristics of healing abutments can influence how bacteria stick to them and form biofilms [15]. Customized abutments, often made from materials like PMMA or composite resins, might have different surface properties compared to pure titanium, which could affect the microbial environment. Understanding these differences is crucial for assessing the long-term health of the tissues around the implant and the risk of gum disease around implants.

Clinical Implications

What we've learned from this systematic review offers valuable insights for dentists in their daily practice, especially when placing immediate implants in areas where esthetics are key. Using customized healing abutments, particularly those made with CAD/CAM technology, is a powerful tool for dentists who want to achieve the best possible esthetic results. They offer a predictable and precise way to shape the gum tissues around the implant, leading to restorations that look more natural and blend in beautifully. This is especially important when it's crucial to preserve the original gum architecture and the little gum triangles between teeth for patient satisfaction.

The digital process involved in making CAD/CAM customized abutments brings several advantages. These include greater precision, less time spent making adjustments at the dental chair compared to manual shaping, and the ability to design the emergence profile beforehand [16, 18]. This can make the entire restorative process smoother and potentially more efficient. Dentists should seriously consider using these custom solutions, especially for patients with thin gum tissue types or when significant gum shaping is needed to get that perfect emergence profile.

However, deciding to use customized healing abutments also involves practical considerations. Making these abutments often requires extra lab work and specialized equipment, which can mean higher costs and potentially a longer initial planning phase compared to simply picking a standard titanium abutment. So, dentists and patients need to have an honest conversation about the costs versus the potential esthetic and soft tissue benefits. Patient expectations about how their smile will look should be thoroughly discussed, and the advantages of customized abutments in meeting those expectations should be clearly explained.

Limitations of the Review

Even though we used a systematic approach, this review has some limitations that we need to keep in mind when interpreting our findings:

- **Diverse Studies:** A big limitation is how different the included studies were. This variation covered everything from the study designs (RCTs, prospective, retrospective) to the patient groups (e.g., where the tooth was pulled, bone quality), the specific implant systems and designs, the materials used for customized abutments, the surgical methods (e.g., whether bone grafting was done, how the gum was cut), the ways they measured outcomes (e.g., different techniques for measuring soft tissue and bone changes), and how long patients were followed. This wide range meant we couldn't combine the data statistically in a meta-analysis, which would have given us a single, precise estimate of the effect. Instead, we presented our findings as a qualitative summary, which, while informative, might not be as strong as a statistical analysis.
- **Small Patient Numbers:** Several of the studies we included had relatively small numbers of patients. Small sample sizes can make it harder to detect real differences between groups, potentially leading to false negative results. This might explain some of the inconsistencies we saw, especially concerning bone loss around the implant.
- **Potential for Publication Bias:** Our review mainly included studies published in English and found in major databases. This approach carries a risk that studies with statistically significant or "positive" results are more likely to get published than those with non-significant or "negative" findings. This could potentially make the benefits of customized healing abutments seem greater than they truly are.
- **Varied Measurement Methods:** Even though we tried to group similar outcomes, the specific ways

soft tissue and bone changes were measured varied across studies (e.g., different X-ray techniques, digital versus manual measurements). This inconsistency can introduce errors in measurement and make direct comparisons tricky.

- **Limited Long-Term Data:** While some studies followed patients for up to 36 months, we really need longer-term studies (like 5-10 years) to definitively assess how stable the gains in soft tissue and bone levels are over time. The initial benefits seen with customized abutments need to be confirmed over extended periods to truly understand their long-term clinical importance.
- **Lack of Microbiological Data:** The absence of comprehensive information on how customized versus standard abutments affect bacteria and cells is a significant gap. This area is crucial for understanding how well the materials are tolerated by the body and any potential long-term risks of inflammation around the implant.

Future Research Directions

To address the limitations we found in this systematic review and to provide more solid evidence for dentists, we recommend several areas for future research:

- **High-Quality Randomized Controlled Trials (RCTs):** We urgently need more high-quality RCTs with enough patients to be statistically meaningful. These studies should follow strict rules for randomization, making sure that both patients and researchers don't know which treatment is being given (blinding), and thoroughly report all their findings.
- **Standardized Measurements and Reporting:** Future studies should agree on standard ways to measure gum tissue dimensions (e.g., consistent reference points, using 3D digital imaging), bone level changes (e.g., standardized X-ray techniques and analysis), and esthetic outcomes (e.g., using validated PES/WES scores). Following reporting guidelines like CONSORT (for RCTs) and STROBE (for observational studies) would make studies easier to compare and allow for future meta-analyses.
- **Long-Term Follow-up Studies:** Studies that follow patients for extended periods (e.g., 5 years or more) are essential. This will help us evaluate the long-term stability of the soft tissue and bone improvements achieved with customized healing abutments and see how they affect the risk of implant-related complications over time.
- **Material-Specific Comparisons:** More research is needed to compare different materials used for customized healing abutments (e.g., PMMA, composite, zirconia) and how the body reacts to them, including their effect on bacteria and inflammation. This would help us figure out if certain materials are better tolerated or less likely to cause bacterial buildup.
- **Impact on Peri-Implantitis Risk:** Future studies should investigate whether the improved gum seal and emergence profile created by customized abutments actually help protect against peri-implantitis, which is a major long-term problem with dental implants. This would involve looking at clinical signs (like probing depth and bleeding gums) and bone loss on X-rays in relation to peri-implantitis.
- **Patient-Reported Outcomes (PROs):** While some studies touched on esthetics, including more comprehensive patient-reported outcomes, such as how the treatment affects their overall oral health-related quality of life and their satisfaction with both the look and function of their new teeth, would give us a more complete picture of the patient experience.
- **Cost-Effectiveness Analysis:** Research that looks at whether customized healing abutments are worth the extra cost compared to standard ones, considering both material costs, chair time, and long-term results, would be very valuable for dentists making decisions.

By focusing on these research areas, the dental community can build a stronger and more complete understanding of how customized healing abutments can truly optimize the outcomes of immediate implant placement.

Conclusion

This systematic review, though limited by the variety of studies available, suggests that custom-designed healing abutments offer clear advantages over standard titanium ones when it comes to fostering healthy gum tissue healing and achieving better esthetic results after

immediate dental implant placement in fresh extraction sockets. The ability of these customized abutments to precisely guide the gum tissue as it matures and to perfectly recreate the natural tooth's emergence profile seems to lead to more stable gum dimensions and a more harmonious, natural-looking implant restoration.

While the evidence shows that both types of abutments are equally good for the implant to fuse with the bone, the impact of customized abutments on bone stability around the implant isn't as consistently proven and definitely needs more research. Information on how these abutments affect bacteria and cells is currently scarce, which is a crucial area for future studies.

From a practical standpoint, customized healing abutments are a valuable tool for dentists aiming for excellent esthetics in immediate implant cases, especially in the front of the mouth. However, dentists also need to consider the higher cost and more complex procedures involved in making them. To get more definitive answers, future research should prioritize well-designed, adequately powered randomized controlled trials. These studies need to use standardized methods, follow patients for longer periods, and thoroughly assess both the hard and soft tissues, as well as biological factors and what patients themselves report. This will ultimately help us develop evidence-based guidelines to make immediate implant treatments even more predictable and successful.

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