Influence of Abutment Material on Stability of Peri-implant Tissues: A Systematic Review

Tomas Linkevicius, DDS, Dip Pros[1]/Peteris Apse, Prof, DDS, Dip Pros, MSc, Dr Hab Med[2]

Purpose: *The aim of this systematic review was to evaluate available evidence for a difference in the stability of peri-implant tissues between titanium abutments versus gold alloy, zirconium oxide, or aluminum oxide abutments.* ***Materials and Methods:*** *Studies were identified by examining several electronic databases and major dental implant, prosthetic, and periodontal journals. To be selected for the preliminary article pool, the article must have been written in the English language and published from 1980 to March 2007. Articles were sorted based on the nature of the study. In vitro studies and literature reviews were excluded. The included articles were clinical, human histology, and animal studies. Case reports, case series, uncontrolled clinical trials, and clinical studies with teeth treated as a control were excluded from the final review.* ***Results:*** *The initial article pool included 40 articles of which 9 met the inclusion criteria: 3 animal studies, 2 human histological studies, and 4 randomized clinical trials. Soft tissue recession was not accurately measured in the included clinical studies. Assessment of peri-implant tissues around zirconium oxide and titanium abutments was described only in animal and human histologic studies. Due to differences in study types, timing of follow-ups, and outcome variables, meta-analysis could not be performed.* ***Conclusions:*** *Included studies revealed that titanium abutments did not maintain a higher bone level in comparison to gold alloy, aluminum oxide, or zirconium oxide abutments. However, there is a lack of information about the clinical performance of zirconium oxide and gold alloy abutments as compared to titanium abutments.* Int J Oral Maxillofac Implants 2008;23:449–456

Key words: *abutment, aluminum, biologic width, crestal bone loss, gold alloy, implant, peri-implant soft tissues, zirconium*

Crestal bone stability and healthy soft tissues are considered necessary for the long-term success of implant-supported restorations. If these 2 parameters are considered, implant therapy can be a reliable treatment with an impressive outcome.[1,2] However, peri-implant tissues are constantly challenged by various hazards. Bacterial plaque,[3] loading,[4] and prosthetic manipulation[5] are factors that can have an adverse effect on implant success.

Research has shown that bone loss of up to 1.5 mm after the first year and 0.2 mm in subsequent years with mucosal recession are inevitable in implant restorative treatment.[6] Abutment material and other characteristics have been perceived as factors affecting the stability of the mucosa and crestal bone. Abrahamsson et al[7] claim that abutment material may play an important role in the prevention of crestal bone and soft tissue recession.

Titanium, gold, base metals, and zirconium or aluminum oxide ceramics are available for prosthetic implant abutment fabrication. Biologic reliability of these materials has been analyzed in various experiments ranging from in vitro tests to randomized clinical trials (RCTs). Numerous papers show a similar response of peri-implant tissues to titanium and aluminum oxide abutments.[8,9] Recently, some new evidence from animal and clinical studies has contradicted the established belief about abutment material influence on crestal bone loss and soft tissue recession.[10] Consequently, the field would greatly benefit from a comprehensive review of the literature on the subject matter.

[1]Private Practice, Vilnius Implantology Center, Kalvariju str. 121-2, LT-08221, Vilnius, Lithuania.
[2]Professor, Department of Prosthodontics, Riga Stradina University, Dzirciema iela 20, Riga, LV 1007, Latvia.

Correspondence to: Dr Tomas Linkevicius, Vilnius Implantology Center, Kalvariju str. 121-2, LT-08221, Vilnius, Lithuania. Fax: +370 8 5 2728569. E-mail: linktomo@gmail.com

Table 1 Included Studies

Publication	Study	Sample size and species	Materials tested	Follow-up	Bone loss	Recession	Remarks
Abrahamsson et al[7]	Animal histology	5 dogs, 30 implants	Titanium, aluminum oxide, gold alloy, dental porcelain	6 mo	Ti: 0.78 mm; Al: 0.80 mm; Au = 1.80 mm; porcelain: 1.26 mm	"Marked soft tissue recession"	Two-piece implants, second-stage surgery, abutment manipulations
Abrahamsson and Cardaropoli[10]	Animal histology	4 dogs, 32 implants	Titanium, gold	6 mo	NR	NR	One-piece implants, study reported total peri-implant seal extension around tested materials
Kohal et al[22]	Animal histology	6 monkeys, 24 implants	Titanium, zirconium	14 mo	NR	NR	Study reported total height of peri-implant soft tissues around tested implants
Degidi et al[23]	Human histology	5 patients	Titanium, zirconium	6 mo	NR	NR	Histological evaluation of gingival biopsies
Arvidson et al[24]	Human histology	20 patients	Titanium, sapphire (aluminum oxide)	At least 3 y	NR	NR	Study evaluated structural differences
Vigolo et al[25]	Clinical trial	20 patients, 40 implants	Titanium, gold	4 y	Ti: 0.4 mm; Au: 0.4 mm	NR	In the test group, indi vidual UCLA gold abutments were used
Andersson et al[26] (1)	Clinical trial	60 patients, 69 abutments	Titanium, aluminum oxide	1 y	Al: no bone loss	"Minor changes"	Separate evaluation of 1-year follow-up group
Andersson et al[26] (2)	Clinical trial	15 patients, 20 abutments	Titanium, aluminum oxide	3 y	Al - gain of bone 0.1 mm	"No changes"	Separate evaluation of 3-years follow-up group
Andersson et al[27]	Clinical trial	32 patients, 103 abutments	Titanium, aluminum oxide	2 y	Ti: 0.4 mm; Al: 0.2 mm	"Relatively stable"	Earlier report of the same study
Andersson et al[28]	Clinical trial	30 patients, 103 abutments	Titanium, aluminum oxide	5 y	Ti: 0.4 mm; Al: 0.3 mm	"Changes of mucosal level"	Later report of the study

NR = not reported.

Discussion of the link between abutment material and peri-implant tissues is usually a part of literature reviews on biologic width around implants.[11–14] However, traditional reviews are susceptible to publication selection bias.[15] Available data should be re-evaluated in the light of evidence-based dentistry, and systematic review is probably the best method to accomplish this goal.[16] Therefore, the major objective of this paper is to examine currently available information as to whether titanium abutments maintain a higher stability for peri-implant tissues in comparison to gold, zirconium, and aluminum abutments.

MATERIALS AND METHODS

To investigate whether there is a difference in the stability of peri-implant tissues around titanium abutments compared to gold alloy, zirconium oxide, and aluminum oxide abutments, an extensive literature search was performed. Studies were identified by examining several electronic databases, such as PubMed, Embase, and the Cochrane Central Register of Controlled Trials. For these searches, key words used were *abutment*, *implant*, *biologic width*, *peri-implant soft tissues*, *crestal bone loss*, *zirconium*, *gold*, *aluminum*, and *gingival recession*. The search was restricted to the articles published in the English language from 1980 to September 2007.

Next, journals such as *Clinical Oral Implant Research, Journal of Clinical Periodontology, International Journal of Oral & Maxillofacial Implants, International Journal of Periodontics and Restorative Dentistry, International Journal of Prosthodontics, Journal of Periodontology, Journal of Prosthetic Dentistry, Periodontology 2000, Implant Dentistry, Journal of Oral Implantology, Journal of Periodontal Research,* and *Clinical Implant Dentistry and Related Research* were searched for additional full-text articles for the years 1990 to 2007. All publications were grouped by the type of the study—animal studies, human histologic studies, clinical trials, in vitro studies, and traditional reviews. To determine which studies would be included in the meta-analysis, several sets of criteria were used depending on the type of the study. The following inclusion criteria were applied to animal studies: *(1)* the number and type of tested animals should be clearly mentioned in the study, *(2)* sample size of test

Table 2 Excluded Studies

Publication	Study type	Reason for exclusion
Fartash and Arvidson[8]	Prospective study	No control
Henriksson and Jemt[9]	Prospective study	No control
Listgarten et al[11]	Review	No inclusion/exclusion criteria
Myshin and Wiens[12]	Review	No inclusion/exclusion criteria
Weber and Cochran[13]	Review	No inclusion/exclusion criteria
Lindhe and Berglundh[14]	Review	No inclusion/exclusion criteria
Glauser et al[29]	RCT	Teeth as a control
Chang et al[30]	RCT	Teeth as a control
Rompen et al[34]	Critical review	No evaluation of clinical trials
Mengel et al[39]	Clinical study	Case report
Kan and Rungcharassaeng[40]	Clinical study	Case series
Holt et al[42]	Review	No inclusion/exclusion criteria
Klokkevold and Newman[43]	Review	No inclusion/exclusion criteria
Kawahara et al[44]	In vitro	Low clinical relevance
Guy et al[45]	In vitro	Low clinical relevance
Chehroudi et al[46]	In vitro	Low clinical relevance
Mustafa et al[47]	In vitro	Low clinical relevance
Kim et al[48]	Animal histology	Use of subcutaneous implants
Akagawa et al[49]	Clinical and histologic study	No control
Hashimoto et al[50]	Human histology	No control
Fartash et al[51]	Animal histology	No control, small sample size
Steflik et al[52]	Clinical trial	No control, small sample size
Arvidson et al[53]	Animal histology	No control
Boudrias et al[54]	Clinical study	Case report
Heydecke et al[55]	Clinical study	Case report
Kohal and Klaus[56]	Clinical study	Case report
Kastenbaum et al[57]	RCT	Teeth as a control
Berge and Grønningsaeter[58]	Prospective study	No control
Fartash et al[59]	Prospective study	No control
Fartash et al[60]	Prospective study	No control
Canullo[61]	Prospective controlled study	Teeth as a control

animals should be no less than 4 in each treatment category,[17] *(3)* test and control groups should be included, *(4)* studies should have a clear outcome, and *(5)* studies should examine oral implants. Human histologic studies were reviewed for the presence of *(1)* test and control groups, *(2)* clear outcome, and *(3)* examination of oral implants. Clinical studies were included if they reported *(1)* a clear outcome of the experiment, *(2)* a control group of titanium abutments or 1-piece implants, and *(3)* at least 12 months of follow-up analysis. The outcome was considered clear if a study reported soft tissue recession and/or crestal bone loss.

RESULTS

The initial article pool included 40 articles. Standard reviews were excluded because of possible study selection bias. In vitro studies were excluded because of their limited clinical relevance.[18,19]

Subsequently, 29 publications were subjected to additional evaluation, namely 6 animal studies with dog and monkey models, 3 human histologic studies, and 20 clinical studies. Clinical studies were as follows: 7 RCTs (level 1b), 1 prospective controlled (level 2a), 7 prospective uncontrolled studies (level 2b), 1 case series, and 4 case reports (level 4).

The extensive examination resulted in the final sample of 9 articles, namely 3 animal studies, 2 human histologic studies, and 4 RCTs (Table 1). Case reports, uncontrolled clinical trials, and RCTs with teeth treated as a control were excluded. The excluded articles and the reason for their exclusion are listed in Table 2.

Meta-analytic methodology was not applied in the current paper because of the variation in types of experimental characteristics. This decision was based on the premise that meta-analysis can only be performed when the studies share sufficient similarity to justify a comparative analysis.[21]

Animal Histologic Studies

Abrahamsson et al[7] compared reaction of peri-implant tissues on titanium, gold alloy, and aluminum oxide abutments and abutments individualized with dental porcelain. Thirty 2-piece titanium implants were placed in 5 dogs. Distance from implant-abutment junction to first bone-implant contact was considered to reflect the actual bone loss. Histometric observations showed that bone loss was 0.78 around titanium (control) abutments, 0.80 mm around aluminum oxide abutments, 1.80 mm around gold alloy abutments, and 1.26 mm around dental porcelain abutments. Clinical evaluation showed marked soft tissue recession around gold alloy abutments.

Kohal et al[22] compared zirconium oxide and titanium abutments. A sample of 12 implants of each kind was placed in 6 monkeys. Later, zirconium and titanium abutments were cemented on the implants. Histologic assessment of specimens did not reveal any statistically significant differences between compared materials. The mean height of soft peri-implant tissues was 5 mm around the titanium implants and 4.5 mm around the zirconium implants.

Abrahamsson and Cardaropoli[10] tested 1-piece gold alloy and titanium implants in terms of their ability to develop stable peri-implant tissues. During the experiment, 32 implants were placed in 4 dogs. Histologic analysis reported vertical extension of soft peri-implant tissues around implants from the margin of mucosa to the first bone-implant contact. This distance around titanium implants varied from 3.44 to 3.71 mm, while gold implants developed dimensions in the range of 3.46 to 3.71 mm.

Human Histologic Studies

Degidi et al[23] performed a histologic study in which soft tissue responses to titanium and zirconium healing caps in 5 patients were compared. After the healing period of 6 months, gingival biopsy specimens were obtained from test and control implant sites. Histologic analysis revealed that inflammatory infiltrate prevailed at titanium specimens in comparison to zirconium.

Arvidson et al[24] compared soft tissues around 1-piece sapphire (aluminum oxide) and titanium implants in 20 patients. The study evaluated 10 implants of each kind with a follow-up at least of 3 years. Biopsies showed a very similar composition of peri-implant tissues between tested implants.

Clinical Studies

In a 4-year prospective controlled randomized trial with a split-mouth design, Vigolo et al[25] compared titanium and gold alloy abutments, which were restored with metal ceramic crowns in 20 patients. Each patient received 2 implants and subsequently 2 abutments, 1 gold alloy and 1 titanium. After 4 years of follow-up, peri-implant tissues showed no difference in response to gold alloy or titanium abutments in that particular patient population.

In Andersson et al's clinical randomized controlled multicenter study,[26] aluminum oxide abutments were compared to titanium abutments. The first group consisted of 60 patients, who received 34 test sintered aluminum oxide abutments with 35 control titanium abutments and were observed for 1 year. The second group of patients consisted of 15 individuals who were supplied with 10 test and 10 control abutments with a follow-up period of 3 years. In the first group, no bone loss around ceramic abutments was recorded after 1 year, while the second group encountered 0.3 mm loss after 1 year and 0.1 mm gain of bone after 3 years of follow-up. The level of peri-implant mucosa at ceramic abutments in both groups showed only minor changes; however, no exact measurements were provided.

Andersson et al[27] published a 2-year report from an ongoing 5-year multicenter study. A sample of 32 patients took part in this study and received a total of 103 implants. For the support of 36 fixed partial dentures, 53 aluminum oxide ceramic and 50 titanium abutments were connected. Soft tissue around abutments and adjacent teeth appeared healthy. The level of the peri-implant mucosa was relatively stable in relation to the abutment/crown. No differences were recorded between ceramic and titanium abutments regarding bleeding of the peri-implant mucosa. Minimal marginal bone loss was recorded after 1 year, which was slightly higher at titanium (0.4 mm) than at ceramic (0.2 mm) abutments.

The 5-year report of the same experiment was published by Andersson et al[28] in 2003. Thirty patients and 29 fixed partial dentures were evaluated at that time. Average marginal bone loss around ceramic abutments after 1, 3, and 5 years was 0.3 mm (0.4 mm around titanium abutments). No significant differences between test and control abutments in bleeding on probing and plaque accumulation were recorded. However, more frequent soft tissue recession was noticed around ceramic abutments.

DISCUSSION

The purpose of this systematic review was to determine whether titanium abutments maintain peri-implant tissue stability at a higher level than any other prosthetic abutment material. Due to strict inclusion/exclusion criteria, only a small portion of the initially selected articles were accepted for the

final review. Some of the excluded papers were clinical trials that were well-designed and employed randomization but included teeth as a control group.[29,30] It is well known that randomized controlled clinical trials typically provide the most reliable evidence; however, they have inherent drawbacks in comparison to other types of studies.[31] Additionally, some concern has been expressed that there is a tendency to exalt randomized trials while neglecting evidence of lower rank.[32] Therefore, it may be beneficial to compare the results of this study to those that did not meet the inclusion criteria. This should not be considered an attempt to increase the veracity of the review but rather an attempt to determine whether there is any difference in results of included and excluded research.

The comprehensive review included separate evaluation of animal, human histology, and clinical studies, because the significance of different study types on the same subject varies, with clinical being the most reliable and animal being the least reliable.[33]

Abutment material effect on peri-implant tissues has been discussed previously in a narrative review by Myshin and Wiens.[12] As no inclusion/exclusion criteria were formulated, the reader was left to rely on the authors' subjective selection of the studies. In a recent critical review, Rompen et al[34] analyzed the literature by focusing on the clinical relevance of each study, which resulted in recommendations to avoid using gold alloy and dental porcelain abutments. These conclusions are questionable, as no clinical trials were included in the analyses, and the latter recommendations are based on in vitro and animal studies.

The ability of prosthetic abutment material to form a stable peri-implant seal can be characterized by 2 parameters, namely presence or absence of bone loss and gingival recession. An animal study showed that titanium and Al_2O_3 ceramic abutments can develop stable soft tissue seal. Soft tissues adjacent to gold and porcelain-fused-to-metal abutments showed recession, and significant crestal bone loss occurred; therefore, it was concluded that their biocompatibility could be questioned.[7] In contrast, a later study by Abrahamsson and Cardaropoli[10] showed no difference between soft and hard tissue integration around gold alloy and titanium 1-piece implants. One-piece implants have the abutment incorporated into the implant body; thus, this experiment can also be treated as a titanium and gold alloy abutment assessment. The differences between the 2 studies could be explained in terms of methodologic disparity. The first study used 2-piece implants of the Brånemark System (Nobel Biocare, Göteborg, Sweden). Methods included abutment disconnection and second-stage surgery. The other experiment used custom-made 1-piece implants (Straumann, Basel, Switzerland); therefore, neither abutment disconnection nor second-stage surgery were carried out. In addition, 1-piece implants bypassed the possible effect of implant-abutment interface. There is some evidence in the literature that abutment disconnection,[5] second-stage surgery with flap elevation,[35] and microgap[36] could cause crestal bone loss and/or soft tissue recession.

The third publication included Kohal et al's animal study, in which titanium and zirconium abutments were compared.[22] The study used a monkey model. The experiment showed that zirconium oxide integrated in per-implant tissues as well as titanium. Soft tissue extension and bone apposition did not differ statistically between compared specimens. These findings indicate the equal biocompatibility between zirconium oxide and titanium. As the study did not evaluate soft tissue and crestal bone changes, it can be perceived as a descriptive experiment. However, it should be noted that the nonhuman primates used in the experiment resemble human oral anatomy and histology more than any other animals,[37] ensuring the reliability of the study.

In light of evidence-based dentistry, the implications of animal studies are open to discussion. The similarity of physiology between animals and humans forms the basis for animal studies, and the results obtained have a high degree of relevance for humans, although they cannot be directly generalized to a clinical environment. Of course, not all experiments can be replicated in human samples due to cost and ethical considerations, leaving a clinician to rely on data from animal experiments. However, some researchers have postulated that animal studies have little clinical relevance. In their opinion, even simple case reports have more clinical validity than well-controlled and randomized animal experiments.[38]

Data from animal studies should be subjected to careful interpretation if applied in the clinical environment when reliable clinical evidence is absent. Historically, a prevalent opinion, such as incapability of gold alloy abutments to maintain stable peri-implant tissues, was based only on animal studies, even in light of available contradictory data from clinical case reports and case series.[39,40] In the future, this concept should be reassessed in the face of new clinical and histologic evidence.

Human histologic studies are another type of research that can provide valuable information on soft tissue response to different abutment materials. Usually, human histology studies involve autopsy material or are case reports of implants that were failing or had to be extracted. Controlled trials are rare; therefore, the 2 included studies have signifi-

cant value. In both studies, specimens for histologic analysis were obtained by performing gingival biopsies. In spite of the fact that bone loss and/or gingival recession were not reported, the knowledge, which is obtained from human studies, can increase understanding of abutment material influence on peri-implant tissue health.

Degidi et al[23] concluded that zirconium caps had a more favorable effect on soft peri-implant tissues than titanium healing caps. These findings can be attributed to the fact that zirconium is capable of accumulating fewer bacteria than titanium. This, in turn, results in lower inflammation rates.

Arvidson et al[24] reported that the soft tissue structure and composition did not differ around titanium and 1-piece sapphire implants. This study and previously discussed animal histologic experiments show the similarity between titanium and aluminum oxide abutments with respect to influence on peri-implant soft tissues.

To date, there are 3 published prospective randomized controlled clinical trials[26–28] showing stable soft and hard tissues around aluminum oxide abutments. Bone loss did occur but was not statistically different from control titanium abutments, for which biocompatibility was already proven decades ago.[41] All 3 included studies reported precise measurements of bone loss; however, a data pool could not be performed because follow-up periods ranged from 1 to 5 years. Nevertheless, it can be stated that aluminum oxide abutments indeed can develop a stable marginal bone in a clinical situation.

In contrast to crestal bone loss, soft tissue recession was not measured in all of the included studies. Authors reported soft tissues to be "stable" or "minimally receded," which cannot be considered an accurate measurement.

Excluded material consisting of tooth-controlled experiments[29] and uncontrolled prospective studies shows that aluminum oxide abutments can develop stable peri-implant tissues similar to those around titanium abutments.

The most prominent conclusions come from the Vigolo et al[25] experiment, which examined gold alloy and titanium abutments. No significant differences were found between the 2 materials in terms of crestal bone stability. These findings could potentially change the prevailing opinion that gold as an abutment material is responsible for crestal bone loss and gingival recession.

Interestingly enough, zirconium oxide abutments were not compared to titanium abutments in any clinical trial; hence, no considerations about superiority or inferiority of zirconium over titanium as abutment material could be made. However, there is some reliable data from tooth-controlled investigations. In a 4-year study, Glauser et al[29] provided clear evidence demonstrating that zirconium oxide abutments caused favorable reaction of peri-implant tissues. However, a clinical trial comparing zirconium oxide and titanium abutments should be performed.

Finally, it should be stressed that all included studies did not report exact gingival recession measurements. Clinical studies reported empirical observations about the status of peri-implant mucosa or percentage of abutment sites in terms of where those changes occurred, while animal and human histologic experiments provided readers with knowledge about structure and dimensions of soft tissues in contact with different abutments. Therefore, a comprehensive analysis of different studies is critical to understanding whether abutment material is significant for soft tissue behavior.

CONCLUSIONS

Taking the limitations of this analysis and currently available evidence into consideration, the following conclusions can be drawn:

1. **Titanium versus gold:** Due to the contradictory nature of the findings of animal studies, it is still unclear whether titanium is superior to gold as an abutment material. Recent animal histologic evidence shows very similar peri-implant tissue dimensions around implant/abutments of both materials. The evidence from clinical trials shows no difference between gold alloy abutments and titanium abutments in terms of peri-implant bone stability. Therefore, it can be concluded that use of gold abutments should not be considered a risk factor for crestal bone loss and soft tissue recession.
2. **Titanium versus aluminum oxide:** Data from animal studies, human histologic material and clinical trials indicate that peri-implant tissues around aluminum oxide abutments show stability similar to titanium abutments. No statistically significant differences in crestal bone loss were found in the examined studies.
3. **Titanium versus zirconium:** Animal histologic studies showed very similar reaction of peri-implant soft and hard tissues to titanium and zirconium. Human histologic material indicated an even better reaction of human mucosa to zirconium as compared to titanium. However, zirconium oxide abutments were not tested in controlled studies with titanium abutments.

In conclusion, it can be stated that currently there is no evidence that titanium abutments perform better in maintaining stable peri-implant tissues, compared to gold, aluminum oxide, and zirconium oxide abutments. However, additional studies, randomized controlled clinical trials in particular, are needed to examine the subject matter and provide more exact answers to the questions raised. Additionally, it would be beneficial to conduct studies to obtain a precise measurement of peri-implant mucosa recession around different material abutments.

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