Journal of Advances in Medicine and Medical Research

26(12): 1-13, 2018; Article no.JAMMR.41593
ISSN: 2456-8899
(Past name: British Journal of Medicine and Medical Research, Past ISSN: 2231-0614, NLM ID: 101570965)

Junctional Epithelium or Epithelial Attachment around Implant: Which Term is Desirable?: A Review

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Authors' contributions

This work was carried out in collaboration between all authors. Author MK designed the study and performed the statistical analysis. Author RA managed the analyses of the study. Author HP managed the literature searches. Authors FK and MK wrote the protocol and the first draft of the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAMMR/2018/41593
Editor(s):
(1) Dr. Sandra Aparecida Marinho, Professor, Paraíba State University (Universidade Estadual da Paraíba - UEPB), Campus, Brazil.
Reviewers:
(1) F. Armando Montesinos, National Autonomous University of Mexico, Mexico.
(2) Roberta Gasparro, University of Naples Federico II, Italy.
Complete Peer review History: http://www.sciencedomain.org/review-history/25324

Review Article

Received 17th March 2018
Accepted 28th May 2018
Published 29th June 2018

ABSTRACT

Aim: review of previous relevant studies to assess histological differences in gingival tissue around dental implants and natural teeth to answer the question whether the tissue around dental implants is junctional epithelium or it better be named epithelial attachment.
Methodology: An electronic search of three databases (PubMed, Science Direct and Google Scholar) between May 1980 and May 2017 were performed. Full text, Histological and clinical evaluation, Animal and human studies were included.
Result: Of articles selected by each researcher after reading their abstracts, a total of 49 articles were selected after excluding the duplicates. The full texts of these articles were thoroughly read and were discussed. Finally, 45 out of 49 articles were found to be incomplete relevance to our topic based on our criteria and were reviewed. Some differences were seen in epithelial attachment around teeth and implant in terms of thickness, length and adhesion strength; moreover implant characteristics effect on epithelial attachment dimensions around implants.
Conclusion: According to existing studies, it seems that the origin of the epithelium around the

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implants is similar to the junctional epithelium around teeth histologically but there is controversial information on the similarities and differences between the epithelium around the tooth and the implant in terms of thickness, length and adhesion strength. Therefore, it is suggested to use the word “epithelial attachment” around implant instead of “junctional epithelium”.

Keywords: Junctional epithelium; implant; tooth; epithelial attachment.

1. INTRODUCTION

Periodontium includes the gingiva and an attachment apparatus comprising of periodontal ligament (PDL), cementum and alveolar bone. Gingiva is a part of soft tissue lining of the mouth, which is anatomically comprised of gingival attachment, marginal gingiva and interdental gingiva. It can be categorized into junctional epithelium and oral epithelium [1]. Attached gingiva is composed of two components namely connective tissue and junctional epithelium. Morphological variations of gingival epithelium include oral epithelium, sulcular epithelium and junctional epithelium [2]. Junctional epithelium attaches the gingival margin to tooth structure and protects the underlying periodontal tissue from external stimuli and pathogenic microorganisms [3]. Junctional epithelium is primarily formed by the fusion of reduced enamel epithelium (REE) and oral epithelium during eruption of teeth into the oral cavity. On the other hand, previous studies showed that this tissue can form de novo after gingivectomy [1,4]. Junctional epithelium around natural teeth is attached to the enamel via the basal membrane (internal basal lamina) and hemi-desmosomes [3]. Electron microscopic analyses revealed that basal lamina is composed of two components of lamina lucida and lamina densa, and basal lamina is attached to the enamel via the lamina lucida [5]. Light microscopic studies have demonstrated that junctional epithelium around implants (surrounding the implant neck) is structurally similar to the tissue surrounding natural teeth [6]. Several electron microscopic studies have confirmed the presence of an adherent structure at the interface of dental implant and the surrounding epithelium and emphasized on the presence of basal lamina, lamina densa, lamina lucida and hemi-desmosomes in this area [7,8]. These structures have been observed around implants similar to natural teeth [8]. The gingival lamina propria is mainly composed of a dense collagen network accounting for 55-60% of the volume of connective tissue [9]. Considering the absence of cementum and Sharpey’s fibers around dental implants, the main difference in tissue structure surrounding natural teeth and dental implants, which is responsible for different biological widths around them is related to the connective tissue (in terms of type and number of cells and orientation and adhesion of fibers) [10]. Connective tissue around implants attaches to bone parallel to implant abutment while this tissue is oriented vertically around natural teeth [11]. However, some researchers believe that orientation of fibers can be affected by implant material, surface texture and other implant characteristics [12].

Studies on epithelium around dental implants and natural teeth are scarce and controversial; the reason may be absence of accurate histological findings [6,8,13,14]. Junctional epithelium around teeth is formed by the fusion of REE and oral epithelium; however, presence of REE is believed to be not necessary for the formation of junctional epithelium. On the other hand, it has been demonstrated that junctional epithelium around dental implants is merely composed of oral epithelium [15]. Thus, it raises a question whether the tissue around dental implants is junctional epithelium or it better be named mucosal attachment. Considering the controversial information about the gingival tissue around dental implants, this study aims to do a review of previous relevant studies to assess histological differences in gingival tissue around dental implants and natural teeth to answer this question.

2. METHODOLOGY

This review study evaluated human and animal studies published between May 1980 and May 2017 to answer the following questions:

1. What is the origin of junctional epithelium around natural teeth and dental implants?
2. What are the differences in junctional epithelium around immediately loaded and submerged implants?
3. What are the differences in junctional epithelium around bone-level and tissue-level implants?

4. What are the differences in junctional epithelium around platform switching and traditional implants?
5. What is the effect of implant structure on junctional epithelium?
6. What is the width of junctional epithelium in the maxilla and mandible?

An electronic search was carried out in PubMed, Science Direct and Google Scholar databases using the keywords "junctional epithelium" and "epithelial attachment" and "tooth" and "implant" simultaneously. The search was carried out in "all fields" of resources. The titles of the retrieved articles were evaluated, duplicates retrieved by searching the three databases were eliminated and relevant articles were primarily selected for abstract review. Three researchers read the abstracts and excluded irrelevant articles.

Inclusion criteria:

- Full text in English
- Histological and clinical evaluation
- Animal and human studies
- Case reports

Exclusion criteria:

- Non-English articles
- Abstracts
- Letters, editorials, PhD theses
- Non peer-review publications
- Grey literature

3. RESULTS AND DISCUSSION

Of articles selected by each researcher after reading their abstracts, a total of 49 articles were selected after excluding the duplicates. The full texts of these articles were thoroughly read and were discussed by all researchers during several sessions. Finally, 45 out of 49 articles were found to be in complete relevance to our topic based on our criteria and were reviewed. Table 2, 3 and 4 summarizes the important findings of reviewed articles.

Considering the limited and controversial reports about histological origin of junctional epithelium around dental implants and its differences with junctional epithelium around natural teeth, we aimed to do a systematic review on previous studies on this topic to draw a conclusion about the origin of junctional epithelium around teeth and dental implants and their differences. Herein, we discuss the similarities and differences in the structure of junctional epithelium around natural teeth and dental implants. The effect of structural characteristics of implants on shape and structure of junctional epithelium is also discussed.

3.1 Junctional Epithelium around Teeth

Epithelial attachment to enamel is a complex structure composed of internal basal lamina and hemi-desmosomes [16]. Adhesion of this structure to enamel or cementum is mechanical through hemi-desmosomes while connective tissue has vertical mechanical and chemical attachments to tooth surface [17]. Ultrastructurally, junctional epithelium is composed of non-keratinized squamous epithelium with extensive inter-cellular spaces, fine cytoplasmic residues and sparse tonofilaments [18]. During tooth eruption, primary junctional epithelium is formed by the fusion of REE and oral epithelium or REE alone [16,19-21]. Yajima-Himuro et al. [22] in their molecular study confirmed that REE is the origin of junctional epithelium. They showed that ODAM and AMTN are the two enamel proteins that play important roles in formation and regeneration of junctional epithelium [22]. It is believed that primary junctional epithelium is gradually replaced with secondary mature junctional epithelium originated from oral epithelium, which is structurally and functionally similar to the primary junctional epithelium [16]. However, determination of replacement of junctional epithelium by oral epithelium is difficult [16,20,22]; one model to elucidate this issue is de novo formation of junctional epithelium following gingivectomy [23,24]. But even in such assessments, residual junctional epithelium cannot be overlooked and this model is deficient to determine the origin of junctional epithelium [22]. Several studies have evaluated the expression of adhesion proteins involved in epithelial regeneration after gingivectomy and showed that laminin 5 and integrin a6b4 are expressed by marginal cells in internal basal lamina during epithelial regeneration after gingivectomy; These studies also suggested that these two proteins are synthesized by cells derived from oral epithelium [25,26].

Table 1. Summarizes the process of initial evaluation and selection of articles

Database	Number of articles evaluated		Number of articles selected based on title	Number of articles selected based on abstract
Pub Med	1308	Researcher 1	202	58
		Researcher 2	171	51
		Researcher 3	189	53
Science Direct	19	Researcher 1	5	3
		Researcher 2	4	3
		Researcher 3	8	4
Google Scholar	15900	Researcher 1	324	60
		Researcher 2	257	56
		Researcher 3	276	55

Table 2. Important findings of relevant studies reviewed about junctional epithelium around tooth

Author and publication year	Race of humans/ species of animals	Number/gender/ age of patients	Junctional epithelium origin and its characteristics
Lee et al. [7]	Animal	222 samples were collected from 12-16 teethmice	Junctional epithelium was attached by a fibronectin/laminin-integrin-ODAM-ARHGEF5
Yajima-Himuro et al. [22]	Animal	C57BL/6 and C57Bl/6-Tg (CAG-EGFP) mice	Junctional epithelium originated from the reduced enamel epithelium and two enamel proteins involved in formation of enamel (ODAM* and AMTN)
Sugisawa et al. [20]	Animal	Fifty male Sprague–Dawley rats (3 weeks of age)	Laminin 5 and integrin a6b4 derived from oral epithelium are involved in adhesion/migration and formation of junctional epithelium
Nishio et al. [16]	Animal	Thirty adult male Wistar rats	Two proteins namely ODAM and AMTN play a role at the cell-tooth interface. ODAM is likely to be implicated in cellular events during formation and regeneration of junctional epithelium.
Ishikawa et al. [18]	Animal	Twenty-four 9-week-old male Sprague–Dawley rats	Laminin 5 and integrin a6b4 are involved in adhesion of DAT cells to the enamel surface.

**ODAM: Odontogenic ameloblast-associated protein; AMTN: Amelotin; DAT cells: Cells directly attached to the tooth*

Table 3. Important findings of relevant studies reviewed about epithelial attachment around implant

Author and publication year	Junctional Epithelium around tooth/ implant	Race of humans/ species of animals	Number/ gender/ age of patients	Junctional epithelium origin and its characteristics
Iglhaut et al. [17]	implant	Animal and human	Sixty-six studies	Oral epithelium origin
Hashimoto et al. [5]	Single-crystal sapphire endosseous dental implant loaded with functional stress	Animal monkeys	Ten female Japanese monkeys (Macaca fuscata) weighing 7-9 kg	The ultrastructural features of the implant junctional epithelium were almost identical to those of junctional epithelium attached to natural teeth. The innermost cells of implant junctional epithelium were attached to the implant surface by means of basal lamina-like structures (500-1000 A in thickness) and hemi-desmosomes.
Atsuta et al. [7]	A titanium dental implant	Animal rats	Male Wistar rats (6-week old, n ¼ 10)	Ln-5 contributes to the attachment of the PIE* to the titanium surface, and that PIE attached to titanium at the apical portion of the dental implant–PIE interface.
Atsuta et al. [27]	Dental implants	Review article	Scientific articles published between 1977 and 2014	The PIE performs a similar epithelial attachment function to the junctional epithelium, and forms from the oral epithelium within 2-3 weeks after implantation. The PIE has a much lower functional sealing capacity than junctional epithelium. Despite having very similar epithelial structures, PIE-implant connection is much weaker than the junctional epithelium-enamel connection.
Glauser et al. [51]	One-piece mini-implants with different surface topography in surface distal to therapeutic implants	Humans experimental	Five patients received 12 titanium, one-piece mini-implants with oxidized (*n* = 4), acid-etched (*n* = 4) and machined (*n* =4) surfaces	The junctional epithelium attachment to the implant surface was noted; whereas, the collagen fibers and fibroblasts of the connective tissue seal were oriented parallel to the implant. The epithelial attachment was shorter at the oxidized and acid-etched surfaces compared to the machined surfaces.
Canullo et al. [55]	Platform switching implant restorations	Human	Switching and traditional platform implants; 37 peri-implant soft tissue samples from 14 patients	Junctional epithelium showed small and localized inflammatory infiltrates associated with not-well-oriented collagen fibers and increased microvascular density

Author and publication year	Junctional Epithelium around tooth/ implant	Race of humans/ species of animals	Number/ gender/ age of patients	Junctional epithelium origin and its characteristics
Watzak et al. [53]	Three different implant types after 1.5 years of functional loading without oral hygiene 1.Commercially pure titanium 2.Confidence interval 3.titanium plasma sprayed	Animal	Nine healthy mature adult male baboons (Papio ursinus aged 20-26 years with a body weight of 29–35.5 kg)	A histomorphometric evaluation of the sulcus depth, dimension of the junctional epithelium and connective tissue contact resulted in no significant differences between the three implant designs, neither in the maxilla nor in the mandible
Romanos et al. [57]	Immediately loaded implants	Human	Twelve dental implants were placed in the maxilla and mandible of a patient who smoked	The dimensions of junctional epithelium remained almost constant.
Buser et al. [28]	Non-submerged unloaded titanium implants	Animal	Twenty-four implants were placed in 6 beagle dogs	The cells of the junctional epithelium often showed an elongated nucleus with less heterochromatin and a prominent nucleolus, a junctional epithelium similar to natural teeth.

**PIE: Peri-implant epithelium; OSE: Oral Sulcular Epithelium*

Table 4. Length and dimensions of junctional epithelium around implants

Author and publication year	Junctional Epithelium around tooth/ implant	Race of humans/ species of animals	Number/ gender/ age of patients	Junctional epithelium origin and its characteristics
Hermann et al. [48]	The implantogingival junction of unloaded and loaded non-submerged titanium implants	Animal dogs	In 6 foxhound dogs, 69 implants were placed.	The junctional epithelium after 3 months, 6 months and 15 months of healing was 1.16 mm, 1.44 mm, and 1.88 mm.
Abrahamsson et al. [43]	Submerged and non-submerged titanium implants	Animal	Six beagle dogs, about 1-year old, were used in the experiment.	The junctional epithelium extended more apically in the submerged (1.71º0.13 mm) than in the non-submerged (1.18º0.27 mm) implant group.
Blanco et al [54]	Immediate implant	Animal dogs	This study was carried out on five Beagle dogs. Four implants were placed in the lower jaw in each dog immediately after tooth extraction.	The length of the junctional epithelium in the flapless group was 2.54 mm (buccal) and 2.11 mm (lingual). In the flap group, the results were very similar: 2.59 mm (buccal) and 2.07 mm (lingual), with no significant differences observed between the groups.
Abrahamsson et al. [52]	Titanium implants with different surface characteristics ‘smooth OA; ‘rough RA	Animal dogs	Five beagle dogs, about 1 year old	The zone of connective tissue attachment was 1.6 mm at both OA and RA The zone of connective tissue that was facing the abutment was 0.3mm at OA and 0.6mm at RA.
Abrahamsson et al. [56]	Different implant abutments	Animal	Five beagle dogs, about 1 year old	The height of the junctional epithelium was about 2 mm.
Cochran et al. [2]	Unloaded and loaded non-submerged titanium Implants in the canine mandible	Animal dogs	In total, 69 titanium plasma-sprayed and sandblasted acid-etched implants were placed in an alternating fashion in six foxhounds	Junctional epithelium height was 1.88 mm. This measurement was similar to that around teeth.

3.2 Junctional Epithelium around Implants

Peri-implant mucosa is composed of three types of epithelium namely peri-implant sulcular epithelium (PISE), peri-implant epithelium (PIE) and oral epithelium [27]. Several studies have discussed that epithelial attachment around implants (whether titanium or ceramic) is structurally and functionally similar to gingival attachment around natural teeth [28-30]. Some researchers believe that adhesion of junctional epithelium to implant is even stronger than that to teeth [31] but Ericsson et al. reported that resistance to probing in PIE is weaker than that in junctional epithelium-enamel [14]. On the other hand, some studies postulated that a strong bond exists between keratinized epithelium and circular collagen fibers located around implants without any cellular attachment [31]. Hashimoto et al. showed that the structure of epithelium attached to dental implant and its clinical pattern is similar to that of junctional epithelium around natural teeth with the difference that epithelium attached to implants is shorter and thinner and is derived from oral epithelium according to several studies while the origin of primary junctional epithelium around teeth is REE [5]. Several studies indicated that PIE at the inferior parts of the PIE-implant interface attaches to implant surface via basal lamina and hemi-desmosomes [31-33]. However, some other studies stated that apical part of junctional epithelium under light microscope was free from attachments in some parts, which was similar to attachments around teeth in advanced periodontitis [34-37].

Laminin is an extracellular glycoprotein in lamina lucida and is responsible for adhesion of epithelial cells to basal lamina. It is synthesized by epithelial cells. It has been found in dento-junctional epithelium and junctional epithelium-connective tissue interface and also in implant-PIE and PIE-connective tissue interface [7]. Atsuta et al. stated that laminin 5-negative and positive layers in superior-middle parts of the epithelium attached to implant were less than 40nm thick and this area was devoid of hemi-desmosomes. The reason was reported to be release of metal ions from the implant in this area and subsequent down-regulation of synthesis and release of laminin 5 by PIE cells [7]. Thus, they stated that the apical part of PIE is responsible for attachment to implant. After implantation, similar to after gingivectomy around natural teeth, PIE extends apically. It takes four weeks for the internal basal lamina containing laminin 5 to form. The same period of time is required in order for the epithelial attachment to implant from the apical towards the coronal part to accomplish; while, formation of external basal lamina containing laminin 5 in epithelium-connective tissue interface takes only three days [7]. The PIE in apical areas is thin (about 40nm) and has only a few cell layers [38,39]. Around implants, desmosomes and tonofilaments are more developed than those around natural teeth [33]. Also, junctional epithelium around implants is more permeable than that around natural teeth [40]. Berglundh et al. reported that apical cells of junctional epithelium both around dental implants and natural teeth are located 1-1.5 mm above the crestal bone [41]. Transmission electron microscopy is the most ideal tool for evaluation of details of cell to metal attachments. However, information obtained via this technique is limited due to technical problems in obtaining very thin histological sections from the soft tissue-implant interface and also the quality of electron microscopic scans for assessment of the biological nature of junctional epithelium [42].

3.3 Effect of Implant Characteristics on Junctional Epithelium

Studies have demonstrated that the mean dimensions of sulcular epithelium, junctional epithelium and connective tissue between immediately loaded implants and submerged implants are not significantly different and immediate loading has no negative effect on structure of soft tissue and junctional epithelium around dental implants [43-45]. These findings were in agreement with the results of Cochrane et al, since they reported that loaded and unloaded implants had no effect on soft tissue dimensions [2]. In terms of the origin of PIE in immediately or delayed loaded implants, previous studies reported that in immediate loading, the residual junctional epithelium is converted to PIE and attaches to the freshly placed dental implant while in delayed loading two weeks after implant insertion, only oral epithelium is responsible for the formation of PIE; although structurally, differentiation between these two types of PIE is extremely difficult [46]. In contrast, Atsuta et al. showed that one day after implant placement, no junctional epithelium existed and the new epithelium originated from oral sulcular epithelium [7]. Thus, they believed that the origin of PIE in immediate and delayed loading of implant was oral sulcular epithelium

and oral epithelium, respectively and residual junctional epithelium plays no role in formation of PIE. Weber et al. observed that junctional epithelium around submerged implants extended more apically than that around non-submerged implants (1.71mm and 1.18mm, respectively) [47]. These findings were in contrast to those of Abrahamsson et al, who showed that length of PIE around submerged and non-submerged implants was similar and about 2 mm [38]. Both the afore-mentioned studies demonstrated that length of PIE is higher than that of junctional epithelium around natural teeth [38,47]. Such differences in the results of studies are probably attributed to different study designs, methodologies, biopsy procedures, histological techniques used or inflammation of mucosa [43]. Results of animal studies on physical design of implants and its effect on PIE height are variable. Abrahamsson et al. showed that connective tissue around one-piece implants was 1.24 mm while it was 1.87 mm around two-piece implants; however, junctional epithelium and sulcus depth were not significantly different among the groups [43]. Hermann et al. reported greater apical migration and subsequently greater PIE height around bone-level compared to tissue-level implants and reported the probable reason to be the negative effect of micro-gap present between abutment and implant [48]. Their findings were in contrast to those of several other studies regarding adaptation of connective tissue to abutment surface [38,49,50]. Another study compared soft tissue around one-piece mini-implants with acid-etched surfaces and machined mini-implants placed unloaded after eight weeks and showed that PIE height around acid-etched mini-implants was shorter while connective tissue height around these implants was longer. A possible explanation for this difference is that in implants with roughened surfaces, the conductive effect of rough surface on the connective tissue prevents growth and apical migration of epithelium and as the result, PIE height decreases [51]. These findings were in contrast to the results of Abrahamsson et al, and Watzak et al, who found no significant difference qualitatively or quantitatively between machined (smooth) and acid-etched (roughened) abutments or between screw-type or cylindrical-shaped abutments [52,53]. Blanco et al. evaluated the effect of surgical procedure of implant insertion (flap or flapless) on PIE length and found no significant difference between groups [54]. It may be supposed that in the platform switched restoration, connective tissue occupies the area surrounding the horizontal portions of the platform, and the junctional epithelium extends along the abutment and stops at the Implant Abutment Junction [55]. Several studies demonestrated no significant difference between platform switching and traditional platform implants after restoration placement in terms of junctional epithelium dimension and soft tissue inflammation around implants [56,57,58]; however some studies reported a statistically significantly shorter epithelial attachment in sites with mismatched abutments compared with conventionally restored implant sites [55,59]. The difference in the outcomes of the various studies compared with those of the present study may be related to the different planes of sectioning applied in the histological preparations and to the supracrestal positioning of the implants in some instances.

Implant structure and material are among other parameters affecting apical growth of PIE. Soft tissue shows greater apical migration and consequently greater bone loss around gold and gold alloy abutments in contrast to pure titanium and Al2O3 ceramics [2]. Similarly, Abrahamsson et al. reported that titanium or ceramic-based aluminum abutments result in suitable attachment of epithelium and connective tissue with 2 mm width while gold alloy and dental porcelain abutments do not provide a suitable attachment and result in bone loss at the area [60]. On the other hand, a prospective study compared titanium and gold alloy abutments and found no significant difference between the two in terms of bone loss, soft tissue surface or junctional epithelium [52]. A molecular study reported that hemi-desmosomes between epithelium and implant surface were only observed in use of hydroxyapatite and polystyrene materials and no such attachments were noted in use of titanium [3]. Last but not least, Romanos et al. reported that biologic width, sulcular epithelium and connective tissue around implants placed in the maxilla were significantly wider than those around implants placed in the mandible but no significant difference was noted in PIE around implants placed in the maxilla and mandible; although PIE width around mandibular implants was slightly greater than that around maxillary implants (1mm versus 0.8mm) [61].

4. CONCLUSION

According to existing studies, there is controversial information on the similarities and differences between the epithelium around the

tooth and the implant in terms of thickness, length and adhesion strength. in addition, Shape, design, one-stage or two-stage insertion, implant surface and the material used for implant fixtures and abutments affects the conditions of the epithelium surrounding it. Despite these differences, the origin of the epithelium around the implants seems to be similar to the junctional epithelium around teeth histologically. Therefore, It is suggested that the word "epithelial attachment" be used instead of "junctional epithelium" in the periimplant epithelium.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

ACKNOWLEDGEMENTS

The authors would like to thank Dr Fatemeh Mashhadi Abbas for her helpful comments on the histological aspects of the study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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