Review Article

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Performance of attachments used in implant-supported overdentures: review of trends in the literature

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The purpose of this review is to examine the performance of attachments used in implant-supported overdenture (IOD) in both clinical and *in vitro* settings and report the compiled findings, comparisons, and trends in the research literature. Articles published in PubMed on IOD attachment systems and performance were reviewed. Non-original articles were excluded. For each article included, the type of study, number of implants, number of attachment systems, and study outcome were recorded. Of the 283 articles found, 158 met the inclusion criteria. Ninety-four articles were clinical studies and 64 articles were *in vitro* studies. Studies on retention were the most common for *in vitro* studies, and four or more attachment systems were compared in most articles with significant differences in outcome. A clinical outcome of one attachment system was most common for clinical studies, while most studies had neutral outcomes overall. Ball attachment was the most commonly tested IOD attachment system. The trend in the literature showed that there is a large discrepancy between the study designs and outcomes between the clinical and the *in vitro* studies for IOD. Further clinical studies that can validate *in vitro* research should be encouraged to address this discrepancy between the two areas.

Keywords: Dental implants, Denture precision attachment, Overlay denture.

INTRODUCTION

Various types of attachment systems are currently available to restore implant-supported overdenture (IOD). Clinicians have selected IOD attachment systems based on factors such as durability, patient demand, cost effectiveness, technical simplicity, and retention [1]. The successful outcome of IOD therapy is well-documented [2,3], and different types of attachment systems have been compared regarding implant survival, marginal bone loss, soft tissue, retention, stress distribution, maintenance, and complications [4]. Many systematic reviews have concluded that type of attachment system does not significantly influence the factors associated with the overall success of implant overdenture therapy [4-8]. However, the decision-making process to prescribe certain types of attachment system still remains unclear. A review by Andreiotelli et al. [8] has suggested that clinicians seem to use attachment systems based on preference, rather than scientific evidence, due to the high success rate of implants regardless of attachment system.

However, such decisions should be based on a hierarchy of scientific evidence where different study designs provide results of varying "strength [9]." *In vitro* research studies have been utilized widely in implant prosthdontic research for many years; however, due to the lower quality of evidence, clinical validation is necessary. Clinical studies have provided

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valuable scientific evidence regarding IOD attachment systems, yet due to variations in clinical situations, many factors have to be examined carefully in order to provide long-term conclusions on the performance of IOD attachment systems [4]. By understanding the trends in the scientific evidence from both *in vitro* and clinical studies, insights may be gained concerning the differences in the outcomes of the studies, as these may clarify the relationship between the two types. The purpose of this review is therefore to examine the performance of attachments used in IOD in both clinical and *in vitro* settings and report the compiled findings, comparisons, and trends in research available from the literature.

ANALYZING METHODS

An electronic search was performed from the PubMed database with the following keywords: *dental, implant, overdenture, attachment*, and *retention*. There was no limitation on the publication year, and the search included the literature until November 2012. To be included in the review, an article was required to be published in a peer-reviewed journal in English and be an experimental study examining the attachment systems for IOD *in vitro*, *in vivo*, or clinically. The exclusion criteria were the following: non-English articles, articles describing clinical or laboratory technique, case reports, case series, clinical report, letters to the editor, incomplete publications with abstract only, or reviews.

The analysis of the gathered articles was adapted from a methodology by Yuan et al. [10]. The articles on the performance of IOD attachment systems were first separated into clinical or *in vitro* studies. Once they were separated, a framework was established to analyze the articles.

1) The following criteria were used for the *in vitro* studies:
   a. Finite element analysis
   b. Retention
   c. Stress
2) The number of implants used in the study were identified and recorded.
3) The IOD attachment systems used in the study were identified as
   a. Stud or ball
   b. Cast bar and clip
   c. Locator (Zest Anchors, Escondido, CA, USA) or resilient attachment
   d. Magnet
   e. Other
4) The number of attachment systems was compared.
5) Assessment of the outcome of the articles was adapted from a study by Hasenboehler et al. [11] and determined to be
   a. Positive: significant differences between the study groups with positive conclusions and/or positive recommendations; positive data derived from basic science studies
   b. Negative: significant differences between the study groups with negative conclusions and/or negative recommendations; negative data derived from basic science studies
   c. Neutral: no significant differences between the study groups; no clear conclusions or recommendations

Similarly, clinical studies were gathered and analyzed.

1) Within clinical studies, the articles were categorized by
   a. Clinical outcome
   b. Patient perception
   c. Both
2) The observation period for the clinical trial was recorded, and the mean was calculated.
3) The number of implants used in the study was identified and recorded.
4) The IOD attachment systems used in the study were identified as
   a. Stud or ball
   b. Cast bar and clip
   c. Locator or resilient attachment
   d. Magnet
   e. Other
5) The number of attachment systems was compared.
6) Assessment of the outcome of the articles was adapted from a study by Hasenboehler et al. [11] and determined to be
   a. Positive: significant differences between study groups with positive conclusions and/or positive recommendations; favorable clinical outcomes
   b. Negative: significant differences between study groups with negative conclusions and/or negative recommendations; adverse clinical outcomes
   c. Neutral: no significant differences between study groups; no clear conclusions or recommendations

The data were entered into a spreadsheet program (Microsoft Excel, Seattle, WA, USA) and descriptive statistics were used to analyze the data.

RESULTS

From the search, a total of 283 articles were found from the PubMed database and 158 articles met the inclusion criteria. Of the 158 articles, 94 articles were classified as clinical studies and 64 were identified as *in vitro* studies. Table 1 shows the number of studies by the year and distribution of the articles based on the type of study. From 2001 to 2005, the greatest

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number of clinical studies was observed (27), while the number of *in vitro* studies increased from 2006 to 2010 (30).

The distribution of the types of studies is shown in Figs. 1 and 2. Studies on attachment retention (57.8%) were the most common (Fig. 1). For clinical studies, as shown in Fig. 2, clinical outcomes of the attachment systems were the most common (76.6%). Sixty out of 94 (63.8%) clinical studies compared one attachment system to another, while 34 (36.2%) reported the clinical performance of one attachment system for IOD patients. The observation period for the clinical studies ranged from 0.5 to 20 years, and the mean was 3.6 years.

The number of implants in the study ranged from 1 to 4 implants in both clinical and *in vitro* studies. Articles involving two mandibular implants were the most common for both categories of studies (Fig. 3). For the number of attachment systems evaluated in the studies, *in vitro* studies mostly compared four or more groups of attachment systems, whereas clinical studies used one attachment system the most in reporting the outcomes (Fig. 4). Ball attachment was the most common attachment compared, followed by bar attachment with a clip, and then magnets in a comparison (Fig. 5).

Fig. 6 represents the distribution of the study outcomes. The majority of the outcomes for the *in vitro* studies were positive with significant differences or one system preferred over another (79.7%). On the other hand, most clinical studies showed that one attachment system did not perform significantly better than another system (55.0%). Within the 34 studies that reported the outcome of the clinical performance of one attachment system, 24 (70.6%) reported minimal pros-

Table 1. Distribution of studies by category and year.

Year	Clinical (n=94)	*In vitro* (n=64)
1990–1995	5	2
1996–2000	19	11
2001–2005	27	13
2006–2010	23	30
2011–2012	20	8

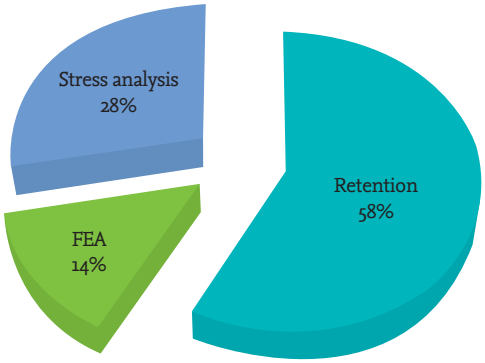

Figure 1. Distribution of *in vitro* studies. FEA: finite element analysis.

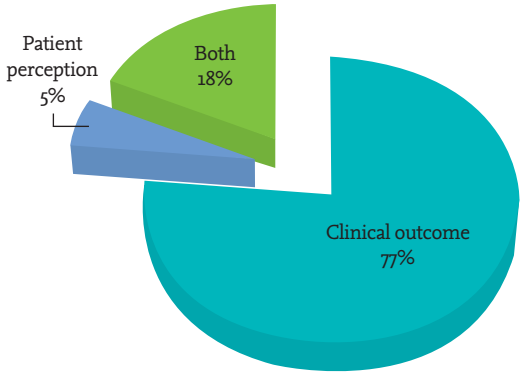

Figure 2. Distribution of clinical studies.

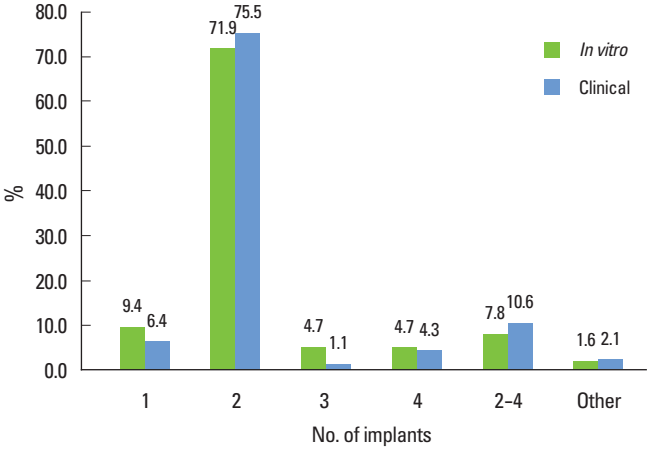

Figure 3. Number of implants used in studies.

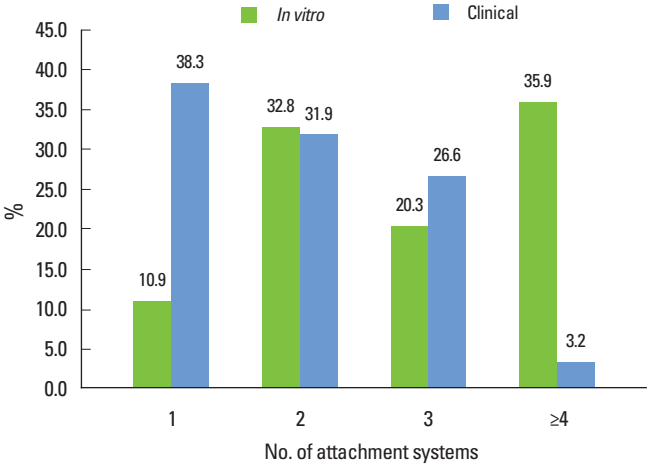

Figure 4. Distribution of attachment systems compared.

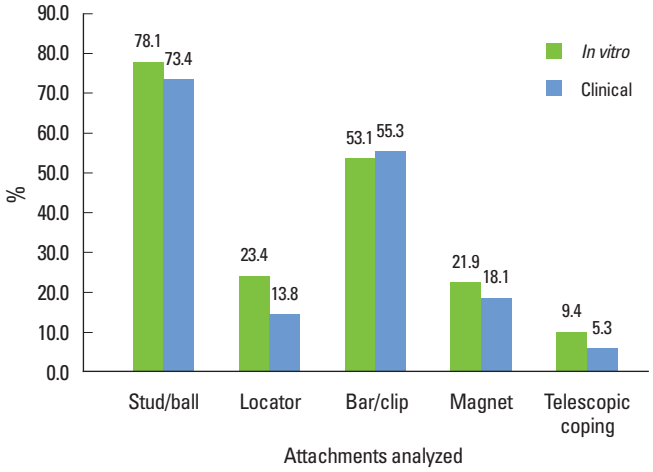

Figure 5. Distribution of attachments analyzed in studies.

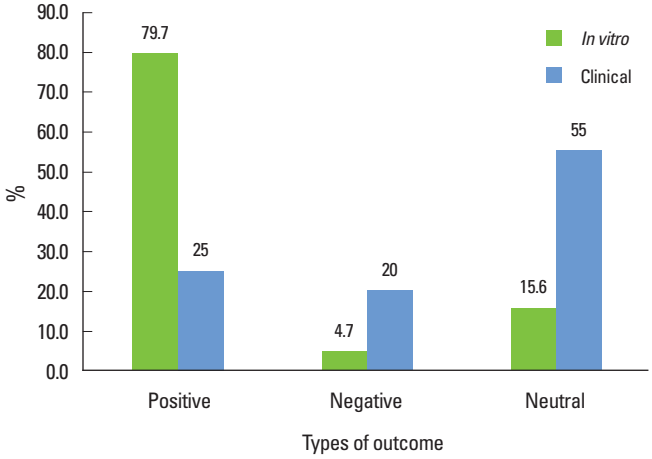

Figure 6. Distribution of study outcomes.

thetic complications and a favorable patient outcome. The other 10 studies (29.4%) reported IOD attachment systems needing a significant number of adjustments, a need for maintenance, wear and loss of material, or need for replacement in a short period of time.

DISCUSSION

The results from this review showed that there are conflicting outcomes between *in vitro* studies and clinical studies examining the performance of IOD attachment systems. While the majority of the *in vitro* studies showed that one attachment system performed better in relation to retention or distribution of stress, clinical performance has shown neutral or no significant differences between attachment systems and in patient perception. This finding is similar to that of the dental implant literature [10]. Yuan et al. [10] showed that, in the dental implant literature, *in vitro* studies were "more likely to report positive outcomes than clinical and animal studies." Dental implant research relies on *in vitro* studies to provide valuable information on the physical properties and mechanical performance [12]. Advancement in computer technology and simulation of the oral environment can provide details such as material properties, friction coefficients of different implant-abutment parts, elastic properties of the jawbone, and realistic loading conditions and mastication [12]. Finite element analysis, with input of accurate elastic properties of bone, modeling geometry, and boundary conditions can provide accurate biomechanical behavior in dental implant studies [12]. However, possibly due to the smaller sample sizes, fewer variables, and lack of randomization, *in vitro* studies may be more likely to report positive outcomes [10,13]. Therefore, it is crucial for these studies to be validated by clinical trials [14,15]. Well-designed clinical research with a high level of evidence can validate the findings from *in vitro* studies and offer new insights for different treatment modalities and clinical outcomes [15,16]. Further clinical studies that can validate *in vitro* research should be encouraged to bridge the gap between the two areas.

The fundamentals behind prescribing IOD should be patient-centered. Two dental implants for mandibular overdenture still remain the most popular treatment modality for treating edentulism, as shown in Fig. 3. The McGill consensus statement [17], along with the York consensus statement [18], advocated for mandibular two implant-supported overdenture as the "first choice standard of care" for edentulous patients. However, it was also interesting to observe other clinical and *in vitro* studies using one or three implants for overdentures. Alsabeeha et al. [15,16] described single implant overdenture as a conservative approach with clinical outcome and patient perception comparable to the traditional two implants. Geckili et al. [19] reported favorable clinical outcomes for three implant-supported overdenture in the mandibular arch. The third implant in between the distal two implants can serve to resist the antero-posterior rotational movement of the overdenture [20]. More clinical evidence of the effects of different numbers of implants for overdentures could prove useful, as implants should be prescribed based on clinical diagnoses and the need of the patient, rather than preference of the clinician.

Each IOD attachment system has unique features that may be selected over others based on different clinical or patient situations. With many attachment systems available for clinicians, it is a challenge to educate future clinicians to have experience in all the attachment systems. Currently, the accreditation standard for dental education programs states that all graduates must be competent in the replacement of teeth including fixed, removable, and dental implant prosthodontic

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therapies, which encompasses IOD [21]. However, predoctoral implant education may be limited to introducing one attachment system and predoctoral students may not be exposed to other types of attachments. For example, Locator attachments are widely used in predoctoral implant programs [22,23]. However, some have reported substantial maintenance requirements [24,25] and graduates may not realize that other attachment systems could improve results. Therefore, prescribing one type of attachment system may become based more on the familiarity of the clinician, rather than evidence-based or long-term clinical outcome. Obtaining clinical experience in using additional attachment systems may have to rely on advanced education programs in prosthodontics or other residency programs. Fundamentally, having extensive knowledge in several attachment systems may be an asset for clinicians to carefully diagnose and use the IOD attachments most suitable for clinical settings such as the number of implants, angulations, jaw relationships, or parafunctional habits.

There are some limitations in this review. The database accessed for the review was limited to PubMed. Other databases such as Medline, Embase, or Cocharane were not accessed. Also, other keywords used in the literature to describe the performance of IOD attachments may not have been included in this search. Therefore, the literature available on IOD attachments may have been underrepresented.

In conclusion, this review of trends in IOD research examined the performance of attachment systems, comparisons, and outcomes in both clinical and *in vitro* settings. The *in vitro* studies generally utilized multiple attachment systems that showed significant differences among them, while the clinical studies generally evaluated only one attachment system with no significant findings. This analysis of the literature showed that there is a large discrepancy between the study designs and the outcomes between the clinical and *in vitro* studies for IOD. Further clinical studies that can validate *in vitro* research should be encouraged to address this discrepancy between the two areas.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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