# Microtensile Bond Strength of Total-Etch and Self-Etch Universal Adhesives Containing 10-MDP: A Systematic Review

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**Abstract:** A systematic review was performed to compare the human dentin microtensile bond strength of universal adhesives with 10-MDP when used as total-etch and self-etch strategies. Literature search was done on October 2019 without limitations on the language of publication, in four databases: PubMed, Web of Science, Scopus, and EBSCO. Additional manual search was done for the grey literature articles: OpenGrey and OpenThesis. Studies that evaluated the dentin bond strength of universal adhesives with 10-MDP using total-etch and self-etch strategy from the year 2000 up till October 2019 were included. The initial search resulted in 5121 references: 2234 from PubMed, 1814 from Scopus, 516 from Web of Science, 553 from EBSCO and 4 from OpenThesis. After full text analysis, 30 references were included in this systematic review. Seven different universal adhesives with 10-MDP were evaluated for dentin microtensile bond strength comparing total-etch and self-etch strategies: Single Bond Universal/Scotchbond Universal (3M ESPE), All Bond Universal (Bisco), Clearfil Universal Bond (Kuraray), G-Premio Bond (GC Corp), Tetric Bond Universal (Ivoclar Vivadent), Ambar Universal (FGM) and One Coat 7 Universal (Coltene). The total-etch strategy improved the dentine microtensile bond strength compared to self-etch strategy for all universal adhesives when stored in all three conditions: 24h, thermocycling and long-term immersion according to ISO (TS 11405:2015(E)). The evidence suggests that microtensile bond strength of universal adhesives containing 10-MDP may be improved utilizing total-etch strategy compared to self-etch strategy. This study provides valuable information on the importance of appropriate dentin adhesives strategy that affect success rate of restorations, which helps clinicians to make informed decisions on the strategy to be used during restorations in practice.

**Keywords:** 10-MDP, Dental bonding, Self-etch, Total-etch, Universal adhesive, Microtensile bond strength, Systematic review.

## INTRODUCTION

A remarkable evolution in the history of modern restorative dentistry is the development of cured composite resins, which made rapid progress in the field of coloured restorations [1]. The main goal in restorative dentistry is to achieve a durable and permanent retention between tooth surface and restorative materials. In recent years, the use of adhesive systems for retention of composite resins has increased in recognition due to their ability to prepare mineralized dental tissue for micromechanical and chemical bonding with resin [2]. The establishment of a successful bond interface between tooth and filling material determined the clinical longevity of restorations [3].

Previously, dental adhesives have been classified based on generation, solvent type, mechanism of smear layer removal, and number of clinical steps [4]. Dental adhesives were classified based on generation due to its complexity, which refers to the timeline of the order of the adhesives development by the dental industry [5]. Based on the adhesive strategies, dental adhesives can be classified into "etch-and-rinse or total-etch," "self-etch" and "(resin-modified) glass-ionomer adhesives" [6].

In total-etch adhesive systems, the initial step of phosphoric acid application is crucial in removing the smear layer, which is continued by rinsing/drying and then application of primer and bond resin separately or in a single solution [7]. With the development of self-etch adhesive systems, the application steps were reduced from three to two, by eliminating phosphoric etching. Acidic monomers of self-etch dentin adhesives does not entirely eliminate the smear layer as it is only able to partially dissolve the hydroxyapatite on the enamel surface.

The development of universal adhesives can be counted as the latest novelties in adhesive dentistry and it has already been clinically utilized since 2011. The new universal adhesives are also commonly known as "multi-mode" or "multi-purpose" adhesives because they may be used as self-etch adhesives, etch-and-rinse adhesives, or selective enamel etching [8]. Most of it contains 10-methacryloyloxydecyl

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dihydrogen phosphate (10-MDP) monomers, composed of a hydrophobic methacrylate group on one end (capable of chemical bonding to methacrylate-based restoratives and cements) and a hydrophilic polar phosphate group on the other (capable of chemical bonding to tooth tissues, metals, porcelain and zirconia) [9]. The favorable features of the 10-MDP monomer makes the universal adhesives practical to be used by dental practitioners, and contributes to the high demand of universal adhesive in the current market.

However, there are multiple manufacturers, which uses different ingredients, component and combination in the adhesives that are being produced in the market. Different methods of testing on the adhesives by researchers also caused confusion to the clinician on which adhesives and technique are to be used to increase the success rate of a restoration.

The hypothesis of this study is that there are differences in microtensile bond strength when using total-etch strategy in universal adhesives compared to self-etch strategy. The aim of this study was to carry out a systematic review of the literature in order to appraise the microtensile bond strength of total-etch and self-etch universal adhesives containing 10-MDP.

## MATERIALS AND METHODS

Preferred reporting items for systematic review and meta-analysis protocols (PRISMA) statement was used as a guideline to report this systematic review [10]. The research strategy of the present work was formulated in accordance to PICO (Problem, Intervention, Comparison, Outcome): permanent teeth in need of restoration (P), restoration of composite using dentin adhesives containing 10-MDP (I), different brand of dentin adhesives containing 10-MDP used in self-etch or total-etch strategy (C) and microtensile bond strength of different 10-MDP containing dentin adhesives (O).

One reviewer (Abdul Razak) assessed the titles and abstracts of all studies, from the year 2000 up till 20th October 2019, in four databases: PubMed, Web of Science, Scopus, and EBSCO. The keywords and search strategy used in Pubmed are listed in Table **1** and was adapted for other databases. This reviewer also manually searched the grey literature articles (OpenGrey, OpenThesis) for additional papers such as those unpublished or has been published in non-commercial from, like thesis. All studies were imported into EndNote X9 3.1 version 19.2.0.13218 software after the screening of articles to remove duplicates.

The full texts of the relevant studies were then checked by two reviewers (Abdul Razak and Mohd Ramzi) independently. Any difference in opinion was sorted out through discussion and consensus of a third reviewer (Ismail). The inclusion criteria were (i) papers published from the year 2000 until 20th of October 2019, (ii) in-vitro/ ex-vivo experimental studies, (iii) samples undergone storage (based on ISO 2015), and (iv) studies which compare microtensile bond strength of total-etch and self-etch universal adhesives. The exclusion criteria were (i) abstract only and non-open access journal articles, (ii) studies on microshear bond strength, macrotensile bond strength and nanoleakage, (iii) universal adhesives without 10-MDP monomers, (iv) studies done on enamel only, (v) primary teeth, (vi) animal studies, (vii) affected and infected dentin, air abrasion dentin and aluminium oxide pretreatment dentin, (viii) repair bond strength, (ix) indirect restoration with dual cure resin cement, (x) cavity preparation prepared by LASER, and (xi) samples prepared by trimming method.

A list of studies included in this review was constructed using a standardized form in Excel 2016 (Microsoft; Redmond, WA, USA) containing the demographic data (year, country), outcomes evaluated, number of teeth, universal adhesive used and predominant failure mode reported in each studies (Table **2**).

**Table 1: Search Strategy Used in PubMed**

| Search Terms |
|---|
| (“Universal dentin adhesive” OR “Universal dental adhesive” OR “Universal dentin bonding agent” OR “Universal dental bonding agent” OR “Universal dentin adhesives” OR “Universal dental adhesives” OR “Universal dentin bonding agents” OR “Universal dental bonding agents” OR “Universal adhesive” OR “Universal adhesives” OR “Universal adhesive system” OR “Multimode adhesive” OR “multi-mode adhesive” OR “multimode adhesives” OR “multi-mode adhesive” OR “multi-mode bond” OR “multimode bond” OR “multi-mode bonding agent” OR “multimode bonding agent” OR “Single Bond Universal” OR “ScotchBond Universal” OR “Prime&Bond Universal” OR “Prime&Bond Elect Universal” OR “Adhese Universal”) AND (“Total etch” OR “Etch and rinse” OR “Self etch” OR “Total etch universal” OR “Etch and rinse universal” OR “Self etch universal” OR “Chemically-Cured Dental Bonding” OR “Self-Cured Dental Bonding” OR “Chemical-Curing of Dental Adhesives” OR “Chemical Curing of Dental Adhesives” OR “Dental Bonding, Dual-Cure” OR “dental primer” OR “Dental Materials” OR “Dental Material” OR “dental resin” OR “Dental Resins” OR “bonding interface” OR “adhesive” OR “methacryloyloxydecyl dihydrogen phosphate” OR “MDP monomer”) |

**Table 2: Demographic and Study Design Data of the Included Studies**

| Study | Year | Country | Number of teeth (per group) | Primary Outcome | Secondary Outcome | Predominant failure mode | Universal adhesive used | Groups (aging or storage time) | Mean microtensile bond strength values (MPa) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Self-etch | Total-etch |
| Muñoz | 2013 | Brazil | 40(5) | dentin μTBS | Nanoleakage (NL) evaluation | Adhesive/ Mixed | Scotchbond Universal/ Single-Bond Universal (3M ESPE) | 24hr immersion | 32.40 | 35.10 |
| | | | | | | | All-Bond Universal (Bisco) | 24hr immersion | 13.40 | 39.30 |
| Luque-Martinez | 2014 | Brazil | 140(5) | dentin μTBS | Nanoleakage (NL) evaluation | Adhesive | All-Bond Universal (Bisco) | 24hr immersion | 22.00 | 40.80 |
| | | | | | | | Scotchbond Universal/ Single-Bond Universal (3M ESPE) | 24hr immersion | 32.30 | 36.20 |
| Marchesi | 2014 | Italy | 60(15) | dentin μTBS | Nanoleakage (NL) evaluation | Adhesive | Scotchbond Universal/ Single-Bond Universal (3M ESPE) | 24hr immersion | 35.30 | 34.80 |
| | | | | | | | | 6 months immersion | 27.60 | 24.30 |
| | | | | | | | | 1-year immersion | 26.80 | 21.90 |
| Wagner | 2014 | Germany | 20(12) | dentin μTBS | Failure mode by light microscope | Adhesive | Scotchbond Universal/ Single-Bond Universal (3M ESPE) | 24hr immersion | 44.00 | 49.10 |
| | | | | | | | | Thermocycling | 48.30 | 46.80 |
| | | | | | | | All-Bond Universal (Bisco) | 24hr immersion | 52.60 | 48.80 |
| | | | | | | | | Thermocycling | 44.70 | 54.60 |
| Ahn | 2015 | Korea | 42(2) | dentin μTBS | Failure Pattern | Adhesive | Single-Bond Universal/ Scotchbond Unversal (3M ESPE) | 24hr immersion | 29.70 | 30.80 |
| | | | | | | | All-Bond Universal (Bisco) | 24hr immersion | 16.30 | 29.10 |
| Chen | 2015 | United States | 200(10) | dentin μTBS | TEM resin-dentin interfaces | Mixed | Scotchbond Universal/ Single-Bond Universal (3M ESPE) | 24hr immersion | 59.90 | 55.70 |
| | | | | | | | | Thermocycling | 55.80 | 47.10 |
| | | | | | | | All-Bond Universal (Bisco) | 24hr immersion | 50.10 | 54.60 |
| | | | | | | | | Thermocycling | 47.80 | 51.10 |
| | | | | | | | Clearfil Universal Bond (Kuraray) | 24hr immersion | 48.00 | 49.10 |
| | | | | | | | | Thermocycling | 44.10 | 42.50 |
| Donmez | 2015 | Turkey | 8(1) | dentin μTBS | Failure Pattern | Adhesive | Single-Bond Universal/ Scotchbond Universal (3M ESPE) | 24hr immersion | 29.50 | 38.00 |
| | | | | | | | | Thermocycling | 26.50 | 35.60 |
| | | | | | | | All-Bond Universal (Bisco) | 24hr immersion | 21.30 | 39.30 |
| | | | | | | | | Thermocycling | 31.50 | 27.00 |
| Muñoz | 2015 | Brazil | 40(5) | dentin μTBS | Nanoleakage (NL) evaluation | Adhesive/ Mixed | Scotchbond Universal/ Single-Bond Universal (3M ESPE) | 24hr immersion | 47.00 | 53.00 |
| | | | | | | | | 6 months immersion | 51.00 | 50.00 |
| | | | | | | | All-Bond Universal (Bisco) | 24hr immersion | 51.00 | 49.00 |
| | | | | | | | | 6 months immersion | 47.00 | 49.00 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sezinando | 2015 | United States | 60(5) | dentin µTBS | Nanoleakage (NL) evaluation | Adhesive | Scotchbond Universal/ Single-Bond Universal (3M ESPE) | 24hr immersion | 35.10 | 33.10 |
| | | | | | | | | 6 months immersion | 30.50 | 26.80 |
| | | | | | | | All-Bond Universal (Bisco) | 24hr immersion | 24.10 | 41.10 |
| | | | | | | | | 6 months immersion | 23.90 | 32.20 |
| Sinhoreti | 2015 | Brazil | 20(5) | dentin µTBS | Confocal microscopy | | Single-Bond Universal/ Scotchbond Universal (3M ESPE) | 24hr immersion | 36.70 | 45.98 |
| Farias | 2016 | United States | 88(11) | dentin µTBS | Failure pattern, extent of resin infiltration into dentin | Adhesive | Scotchbond Universal/ Single-Bond Universal (3M ESPE) | 24hr immersion | 46.90 | 57.50 |
| | | | | | | | | Mechanical loading | 52.60 | 65.20 |
| | | | | | | | All-Bond Universal (Bisco) | 24hr immersion | 37.50 | 57.30 |
| | | | | | | | | Mechanical loading | 41.00 | 59.60 |
| Guan | 2016 | Japan | 45(8) | dentin µTBS | SEM and TEM observation | Adhesive/ Mixed | Scotchbond Universal/ Single- Bond Universal (3M ESPE) | 24hr immersion | 58.90 | 54.80 |
| | | | | | | | | Thermocycling (5000 cycles) | 64.70 | 39.90 |
| | | | | | | | | Thermocycling (10000 cycles) | 49.60 | 20.20 |
| Jang | 2016 | Korea | 24(4) | dentin µTBS | Transmission electron microscopy (TEM) analysis | Adhesive | All-Bond Universal (Bisco) | 24hr immersion | 39.02 | 38.81 |
| Kusdemir | 2016 | Switzerland | 18(3) | dentin µTBS | Failure Pattern | Adhesive/ Mixed | Single-Bond Universal/ Scotchbond Universal (3M ESPE) | 24hr immersion | 21.10 | 24.40 |
| Manfroi | 2016 | Brazil | 24(6) | dentin µTBS | Failure mode-SEM analysis | Mixed | Scotchbond Universal/ Single-Bond Universal (3M ESPE) | 24hr immersion | 31.02 | 39.37 |
| | | | | | | | | 6 months immersion | 40.58 | 36.99 |
| Tekce | 2016 | Turkey | 50(5) | dentin µTBS | SEM | Mixed | Single-Bond Universal/ Scotchbond Universal (3M ESPE) | 24hr immersion | 36.09 | 43.33 |
| | | | | | | | | 12 months immersion | 34.81 | 37.67 |
| | | | | | | | All-Bond Universal (Bisco) | 24hr immersion | 38.36 | 43.81 |
| | | | | | | | | 12 months immersion | 30.07 | 38.54 |
| Zeidan | 2016 | Brazil | 36(6) | dentin µTBS | SEM observation | Coheisve in resin/ Adhesive | Scotchbond Universal/ Single-Bond Universal (3M ESPE) | 1-week immersion | 63.20 | 68.30 |
| | | | | | | | | 6 months immersion | 62.10 | 63.90 |
| | | | | | | | | Mechanical load cycling | 26.10 | 18.80 |
| Zhang | 2016 | England | 200(20) | dentin µTBS | Failure mode-SEM observation | Mixed | All-Bond Universal (Bisco) | 24hr immersion | 49.81 | 54.20 |
| | | | | | | | | 12 months immersion | 7.47 | 20.84 |
| | | | | | | | Clearfil Universal Bond (Kuraray) | 24hr immersion | 48.07 | 49.38 |
| | | | | | | | | 12 months immersion | 19.53 | 11.40 |
| | | | | | | | Scotchbond Universal/ Single-Bond Universal (3M ESPE) | 24hr immersion | 60.13 | 55.97 |
| | | | | | | | | 12 months immersion | 55.09 | 19.96 |
| Nicoloso | 2017 | Brazil | 48(6) | dentin µTBS | Failure Mode | Adhesive/ Mixed | Scotchbond Universal/ Single-Bond Universal (3M | 24hr immersion | 41.70 | 55.00 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | ESPE) | | | |
| Pashaev | 2017 | Turkey | 216(6) | dentin μTBS | Nanoleakage (NL) evaluation | Cohesive | Single-Bond Universal/ Scotchbond Universal (3M ESPE) | 24hr immersion | 37.90 | 35.30 |
| | | | | | | | | 6 months immersion | 35.30 | 32.40 |
| | | | | | | | All-Bond Universal (Bisco) | 24hr immersion | 32.80 | 37.90 |
| | | | | | | | | 6 months immersion | 31.00 | 35.10 |
| Sezinando | 2017 | Portugal | 84(12) | dentin μTBS | Nanoleakage (NL) evaluation | Adhesive | Scotchbond Universal/ Single-Bond Universal (3M ESPE) | 24hr immersion | 68.86 | 54.38 |
| | | | | | | | | 6 months immersion | 63.62 | 51.57 |
| Siso | 2017 | Turkey | 12(3) | dentin μTBS | Nanoleakage (NL) evaluation | Adhesive | Clearfil Universal Bond (Kuraray) | 24hr immersion | 21.80 | 27.74 |
| Sutil | 2017 | Brazil | 96(8) | dentin μTBS | Failure mode | Adhesive | Scotchbond Universal/ Single-Bond Universal (3M ESPE) | 24hr immersion | 32.92 | 33.78 |
| Vermelho | 2017 | Brazil | 56(8) | dentin μTBS | SEM | Mixed | Scotchbond Universal/ Single-Bond Universal (3M ESPE) | 24hr immersion | 24.60 | 47.40 |
| | | | | | | | | 1-year immersion | 20.40 | 34.20 |
| | | | | | | | All-Bond Universal (Bisco) | 24hr immersion | 19.40 | 50.80 |
| | | | | | | | | 1-year immersion | 15.30 | 30.90 |
| Choi | 2017 | Switzerland | 72 (12) | dentin μTBS | Failure mode, confocal laser scanning microscopy (CLSM) analysis | Mixed | G-Premio Bond (GC Corp.) | 24hr immersion | 32.80 | 33.20 |
| | | | | | | | Single-Bond Universal/ Scotchbond Universal (3M ESPE) | 24hr immersion | 29.00 | 31.80 |
| | | | | | | | All-Bond Universal (Bisco) | 24hr immersion | 17.40 | 32.00 |
| Zenobi | 2018 | Brazil | 24(6) | dentin μTBS | Failure mode-SEM observation | Adhesive | Single-Bond Universal/ Scotchbond Universal (3M ESPE) | 24hr immersion | 26.40 | 26.50 |
| Siqueira | 2018 | Brazil | 300(5) | dentin μTBS | Nanoleakage (NL) evaluation | Adhesive/ Mixed | All-Bond Universal (Bisco) | 24hr immersion | 36.00 | 39.60 |
| | | | | | | | Ambar Universal (FGM) | 24hr immersion | 54.20 | 55.70 |
| | | | | | | | Clearfil Universal Bond (Kuraray) | 24hr immersion | 49.50 | 56.60 |
| | | | | | | | One Coat 7 Universal (Coltene) | 24hr immersion | 36.90 | 40.30 |
| | | | | | | | Scotchbond Universal/ Single-Bond Universal (3M ESPE) | 24hr immersion | 49.10 | 54.90 |
| | | | | | | | Tetric Bond Universal (Ivoclar Vivadent) | 24hr immersion | 55.10 | 58.00 |
| Leite | 2018 | Brazil | 30(5) | dentin μTBS | Transdentinal cytotoxicity | Cohesive in hybrid layer/Mixed | Scotchbond Universal/ Single-Bond Universal (3M ESPE) | 24hr immersion | 9.70 | 51.33 |
| Arhun | 2018 | Turkey | 24(2) | dentin | Contact angle | Adhesive | All-Bond Universal | 24hr immersion | 9.30 | 12.70 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | μTBS | measurement | | (Bisco) | | | |
| Hass | 2019 | United States | 30(6) | dentin μTBS | Degree of conversion analysis, hybrid layer morphology observation | Adhesive/ Mixed | Scotchbond Universal/ Single-Bond Universal (3M ESPE) | 24hr immersion | 46.90 | 53.60 |

The methodological quality of the studies was assessed by two reviewers as adapted from previous similar systematic review [11]. The risk of bias was evaluated according to the articles' description of the following criteria: randomization of specimens, sound teeth, blinding of examiner, the presence of control group, fixed measurements of samples, evaluation of failure mode, description of coefficient of variation and sample size calculation. If the authors reported the criteria mentioned above, the article was marked with a "/" on that specific criteria, if the information was not mentioned, the specific criteria was left blank. The articles were rank as having high, medium or low bias according to the number of "/": one to three is rank as high, four to five as medium and six to eight as low (Table **3**).

## RESULTS

A total of 5121 publications were retrieved from various databases: 2234 from PubMed, 1814 from Scopus, 516 from Web of Science, 553 from EBSCO and 4 from OpenThesis. The search strategy used in PubMed is shown in Table **1**.

The study selection process according to the PRISMA statement, was summarized in a flowchart (Figure **1**). The initial literature review generated 3705 records for the screening of titles and abstracts. Subsequently, 3667 studies were excluded, resulting in a total of 38 full-text articles to be analyzed. Out of the 38 studies, 8 were excluded because two studies used trimming method [14, 57], one study evaluates on the photo-initiator system [32], one study used dual-polymerizing composite [31], one study used

PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only

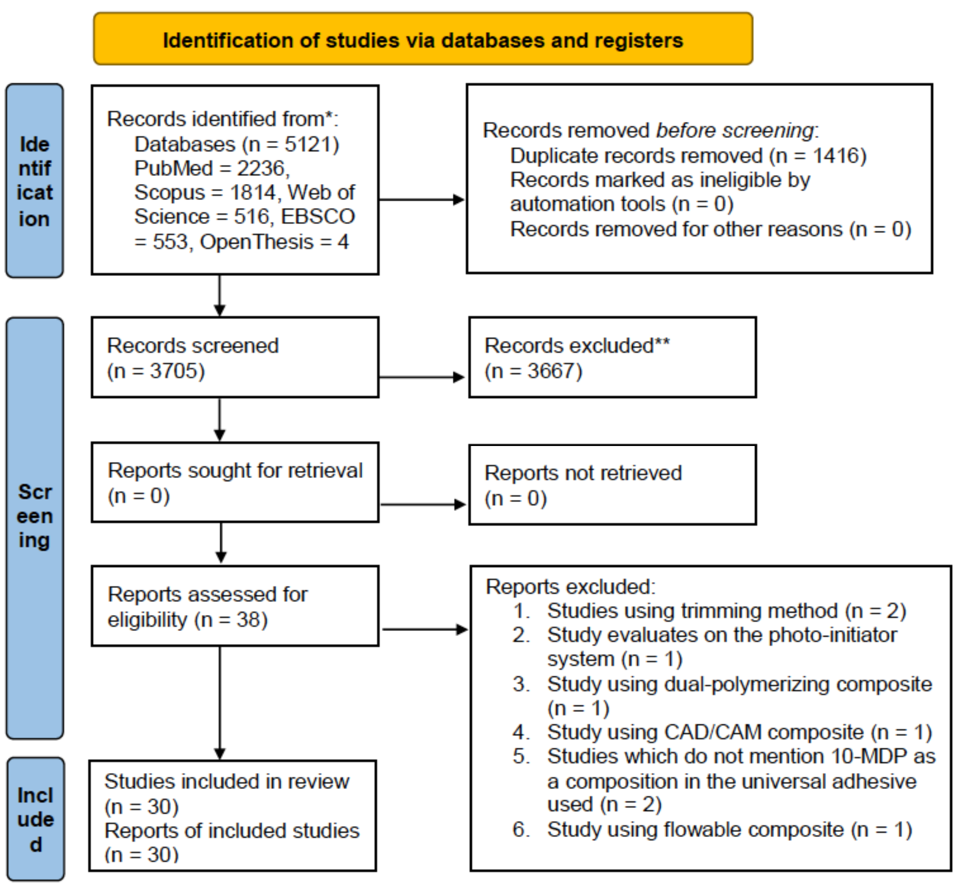


**Figure 1:** Search flowchart according to the PRISMA Statement.

**Table 3: Quality and Risk of Bias Assessment**

| Study | Randomization of specimens | Sound teeth | Control group | Fixed measurements of samples | Evaluation of failure mode | Description of coefficient of variation | Sample size calculation | Blinding of the examiner | Risk of bias |
|---|---|---|---|---|---|---|---|---|---|
| Muñoz (2013) | / | / | / | / | / | | | / | Low |
| Luque-Martinez (2014) | / | / | | / | / | | | | Medium |
| Marchesi (2014) | / | / | | / | / | | | | Medium |
| Wagner (2014) | / | / | / | / | / | | | | Medium |
| Ahn (2015) | / | / | / | / | / | | | | Medium |
| Chen (2015) | / | / | | / | / | | | | Medium |
| Donmez (2015) | / | / | | / | / | | | | Medium |
| Muñoz (2015) | / | / | / | / | / | | | / | Low |
| Sezinando (2015) | / | / | / | / | / | | | / | Low |
| Sinhoreti (2015) | / | / | | / | | | | | High |
| Farias (2016) | / | / | | / | / | | | / | Medium |
| Guan (2016) | / | / | | / | / | | | | Medium |
| Jang (2016) | / | / | | / | / | | | | Medium |
| Kusdemir (2016) | / | / | / | / | / | | | | Medium |
| Manfroi (2016) | / | / | | / | / | | | | Medium |
| Tekce (2016) | | / | | / | / | | | | High |
| Zeidan (2016) | | / | / | / | / | | | | Medium |
| Zhang (2016) | / | / | / | / | / | | | | Medium |
| Nicoloso (2017) | / | / | / | / | / | / | / | | Low |
| Pashaev (2017) | / | / | / | / | / | | | | Medium |
| Sezinando (2017) | / | / | | / | / | | | | Medium |
| Siso (2017) | / | / | | / | / | | | | Medium |
| Sutil (2017) | / | / | | / | / | | | | Medium |
| Vermelho (2017) | / | / | / | / | / | | | | Medium |
| Choi (2017) | / | / | | / | / | | | | Medium |
| Zenobi (2018) | / | / | / | / | / | | | | Medium |
| Siqueira (2018) | / | / | / | / | / | | / | | Low |
| Leite (2018) | | / | / | / | / | | | | Medium |
| Arhun (2018) | | / | | / | | | | | High |
| Hass (2019) | / | / | | / | / | | | | Medium |

CAD/CAM composite [30], two studies do not mention 10-MDP as a composition in the universal adhesive used [40, 25] and one study used flowable composite [7]. Thus, a sum of 30 studies were included in the final analysis of this review. Seven different universal adhesives with 10-MDP were evaluated for dentin microtensile bond strength comparing total-etch and self-etch strategies. From the included studies, a total of twenty-eight evaluated on Single Bond Universal/Scotchbond Universal (3M ESPE). Seventeen studies assessed the bond strength of All Bond Universal (Bisco) and 2 assessed the bond strength of Clearfil Universal Bond (Kuraray). The other universal adhesives assessed were G-Premio Bond (GC Corp), Tetric Bond Universal (Ivoclar Vivadent), Ambar Universal (FGM) and One Coat 7 Universal (Coltene). Table **4** shows the composition, pH and application techniques of the universal adhesives.

There are different types of composite resin used, which include microhybrid composite such as Filtek Z250 (3M Espe, St. Paul, MN, USA), Z100 (3M Espe, St. Paul, MN, USA), Clearfil AP-X (Kuraray, Tokyo, Japan), Spectrum TPH3 (Dentsply, Caulk, Milford, DE, USA), and Opallis (FGM, Joinville, SC, Germany). Four studies used nanocomposite Filtek Z350 (3M Espe, St. Paul, MN, USA) and six studies used nanohybrid composite resin TPH Spectra (Dentsply, Caulk, Milford, DE, USA), TPH Sprectra (Dentsply, Petropolis-RJ,

**Table 4: Universal Adhesive: Composition, pH and Application Procedure**

| Universal Adhesive | Phosphate Ester | Components | Ph | Self-Etch Strategy | Total-Etch Strategy |
|---|---|---|---|---|---|
| Single-Bond Universal/ Scotchbond Universal (3M ESPE) | 10-MDP | **10-MDP**, phosphoric acid ester monomer, **HEMA**, silane, dimethacrylate, Vitrebond (polyacrylic acid) copolymer, filler, ethanol, water, initiators, silane | 2.7 | 1. Apply the adhesive or adhesive mixture to the prepared tooth and rub it in for 20s.<br>2. Gently air-dry the adhesive for approximately 5s for the solvent to evaporate.<br>3.Light cure for 10s. | 1. Apply etchant for 15s.<br>2. Rinse thoroughly with water and dry with water-free and oil-free air or with cotton pellets; do not overdry.<br>3. Apply adhesive as for the self-etch mode. |
| All-Bond Universal (Bisco) | **10-MDP** | **Dimethacrylate resins**, **HEMA**, Ethanol, Water, Initiators | 3.2 | 1. Apply two separate coats of adhesive with agitation for 10–15s per coat<br>2. Evaporate solvent by thorough air-drying for at least 10s. No visible movement of adhesive.<br>3. Surface should have a uniform glossy appearance. If not, repeat steps 1 and 2<br>4. Light cure for 10s | 1.Etch for 15s.<br>2. Rinse thoroughly.<br>3. Remove excess water by blotting surface with an absorbent pellet or high volume evacuation for 1–2s, leaving the preparation visibly moist.<br>4. Apply adhesive as for the self-etch mode. |
| Clearfil Universal Bond (Kuraray) | **10-MDP** | **Dimethacrylate resins**, **HEMA**, Ethanol, Water, Silane, Fillers, Initiators | 2.3 | 1. Apply adhesive and rub it in for 10s.<br>2. Dry the entire cavity wall by blowing mild air for more than 5s until adhesive shows no movement. Use a vacuum aspirator to prevent the adhesive from scattering.<br>3. Light cure for 10s. | 1. Apply phosphoric acid etching gel for 15s, then rinse and dry<br>2. Apply adhesive as for the self-etch mode. |
| G-Premio Bond (GC Corp.) | 10-MDP | **10-MDP**, phosphoric acid ester monomer, **dimethacrylate**, **4-META**, **MEPS**, acetone, silicon dioxide, initiators | 1.5 | 1. Apply adhesive and wait for 10s.<br>2. Dry for 5s at max air pressure.<br>3. Light cure for 10s. | 1. Etch for 10-15s, rinse and dry.<br>2. Apply adhesive and wait for 10s.<br>3. Dry for 5s at max air pressure.<br>4. Light cure for 10s. |
| Tetric Bond Universal (Ivoclar Vivadent) | 10-MDP | **HEMA**, **10-MDP**, **bis-GMA**, **MCAP**, **DEMA**, ethanol, water, highly dispersed silicon dioxide, CQ | 2.5-3.0 | 1. Apply one coat of adhesive to the entire preparation with a microbrush and rub it in for 20s.<br>2. Gently air thin for 5s.<br>3. Light cure for 10s at 1200mW/cm2. | 1. Apply etchant for 10-15s.<br>2. Rinse for 10s.<br>3. Air dry 5s.<br>4. Apply adhesive as for the self-etch mode. |
| Ambar Universal (FGM) | 10-MDP | Methacrylate monomers (**UDMA** and **10-MDP**), photoinitiators, co-initiators, stabilizers, inert silica nanoparticles and ethanol | 2.6-3.0 | 1. Apply two coats vigorously by rubbing the adhesive for 20s (10s each).<br>2. Gently air dry for 10s to evaporate the solvent.<br>3. Light cure for 10s. | 1. Apply etchant for 15s.<br>2. Rinse thoroughly.<br>3. Remove excess water with air.<br>4. Apply adhesive as for the self-etch mode. |
| One Coat 7 Universal (Coltene) | 10-MDP | Methacrylates including **10-MDP**, photoinitiators, ethanol, water | 2.8 | 1. Rub with a disposable brush for 20s.<br>2. Dry gently with oil-free compressed air for 5s.<br>3. Light cure for 10s at 1200mW/cm$^2$. | 1. Apply etchant for 15s.<br>2. Rinse for 10s.<br>3. Air dry 2s.<br>4. Apply adhesive as for the self-etch mode. |

Brazil), Filtek Supreme Ultra (3M Espe, St. Paul, MN, USA), Filtek Z550 (3M Espe, Seefield, Germany), and GrandioSO (VOVO GmbH, Cuxhaven, Germany).

The 30 included studies each used their own method of aging and storing the samples but the most common method of sample storage was for 24 hours in distilled water at 37$^{o}$C. Thermocycling and mechanical loading was also used as an accelerated aging test in the studies included. Long- term storage over 6 months and 1 year were also included. The results of 30 articles reported on the dentin microtensile bond strength of universal adhesive with 10-MDP are summarized in Table **2**. The total-etch strategy improved the dentine microtensile bond strength when compared to self-etch strategy for all universal adhesives when stored in all three conditions: 24 hours, thermocycling and long-term immersion.

The mean microtensile bond strength values (MPa) according to brands of universal adhesives were described in Table **2**. From the 30 analyzed studies, 3 studies manifested a high risk bias, 22 showed a medium risk of bias, and 5 studies showed a low risk of bias. The results are described in Table **3**, based on the criteria considered in the analysis. The criteria that most studies did not report were sample size calculation, description of coefficient of variation and blinding of the examiner.

## DISCUSSION

Out of 38 studies, 8 were excluded because two studies used trimming method [12, 13], one study evaluates on the photo-initiator system [14], one study used dual-polymerizing composite [15], one study used CAD/CAM composite [16], two studies do not mention 10-MDP as a composition in the universal adhesive used [17, 18] and one study used flowable composite [19]. Thus, a sum of 30 studies were included in the final analysis of this review. These differences could affect the result of microtensile bond strength test in an experiment including factors such as pH, temperature, wet or dry bonding procedure and different ageing protocols. Despite the questionable results of some studies, the results obtained using microtensile bond strength test are the most reliable compared to other tests [20]. In these tests, hourglass shaped specimens of approximately 1mm$^2$ bonded area are prepared. The specimens are then loaded to failure. It is suggested that a smaller bonding area will have fewer defects and therefore, is a more valid measured bond strength compared to other tests. The test can be either trimming or non-trimming microtensile test. The specimen preparation of the trimming technique is more complicated than the non-trimming technique. Therefore, this study only compared the result of conventional tensile test using the non-trimming - method [4].

Dental adhesives composed of solutions of resin monomers which helps in the resin dental substrate interaction [5]. The standard compositions of adhesives are acrylic resin monomers, organic solvents, initiators and inhibitors, and sometimes filler particles [21]. Currently, there are many available universal dentin adhesives in the market and different brands of universal adhesive may contain different compositions. These difference in composition may reflect the variety of results found in previous studies. Some brands may include monomers other than 10-MDP such as HEMA, META and bis-GMA, which will affect the reading of microtensile bond strength tests. 10-MDP is the most hydrophobic of all the functional monomers as it contains a long carbon chain backbone which causes it to be resistant to water sorption and hydrolytic breakdown of the resin-tooth interface, thus increases the longevity of the restoration [22]. Besides, the hydrophobic 10-MDP monomers can form ionic bond between the tooth tissues and calcium found in hydroxyapatite (Ca10[PO4]6[OH]2), producing adhesive interfaces that are impervious to biodegradation (Alex, 2015). This characteristic makes it desirable for use in a universal adhesive. The literatures suggest that bond strength of 10-MDP containing universal adhesives with prior acid-etching is greater compared to when using the self-etch strategy, thus, the hypothesis is accepted.

Outstanding clinical properties and easy bonding application of composite resin restorations caused a surge in its clinical utilisation as a restorative material in the past few years [23]. Clinicians and patients most frequently prefer resin-based composites as the options for both anterior and posterior restorations due to its ability to bond to tooth structures with adhesive systems, cost-effective, their similarity to tooth structures in mechanical properties and colour, and direct application at chairside [7].

Besides, difference in ageing method such as thermocycling, which can enhance the process of how the bonding agent degradation occurs in humans could also affect the result of this review [24]. Although there is different ageing process recognized and listed in the ISO (TS 11405:2015(E)), there is still a lack of data on long-term ageing and thermal ageing of universal adhesives which could be directly correlated clinically. Some literature showed that there was degradation of the hybrid layer of the dentin adhesives over 6 months' time. Thus, more studies need to be conducted to evaluate the long-term effect of ageing to the dentin adhesive and to analyze the clinical behavior of latest universal adhesives available in the market.

Out of the 30 included studies, 23 studies showed higher microtensile bond strength for total-etch strategy [25-47]. On the other hand, 7 studies showed higher microtensile bond strength for self-etch strategy, one of it showed significant result [48-54]. One study by Guan (2016), reported significantly higher microtensile bond strength in self-etch strategy, due to better penetration of resin monomers into the dentin substrate which improves quality of the hybrid layer in moist conditions. However, the dissolution of calcium hydroxyapatite crystals using strong acids to demineralized hard tissues, as proposed the adhesion-decalcification (A-D) concept will diminish the ability of creating chemical bond between adhesive resin monomers and hydroxyapatite crystals (Chen, 2015). The smear layer creates a physical barrier which prevents the hybrid layer to fully integrate with the dentin, thus, phosphoric acid is required to remove the barrier and allow a deeper decalcification process of the dentin (Donmez, 2015). Additionally, the hydrophilicity of self-etch adhesives causes the adhesive layer to be more susceptible to water sorption and compromises the tooth-resin bond over time (Sofan, 2017). This was also observed with the universal adhesives in this review where most of the microtensile bond strength in self-etch strategy is lower compared to total-etch strategy. The step of enamel etching in total-ech strategy is important to produce microporosities by demineralization of the inorganic enamel surface which then produces a distinct mechanical bond, eliminates smear layers on the dentine surface and funnels the dentinal tubules [55]. Previous literatures also have proven that prior phosphoric acid etching is able to effectively demineralize the superficial hydroxyapatite and eliminate the smear layer, which is the ideal method to strengthen the bond strength of universal adhesives (Summit, 2014).

There are a total of 30 articles included for full text assessment, 3 articles with high-risk bias were excluded leaving only 27 articles. Out of 27 articles, 22 reported that total-etch strategy is better than self-etch and 5 studies (medium-risk bias) reported higher microtensile bond strength for self-etch strategy. However, the scientific degree of the included studies is one of the limitations of this review.

## CONCLUSION

The findings of this review suggest that microtensile bond strength of universal adhesives containing 10-MDP monomer can be improved by utilizing total-etch strategy compared to self-etch strategy. However, there were limitations with the included studies that would affect the findings of the literature: different procedure done in preparing the samples, different composition, chemical interaction and application technique of the adhesives used in the study, different types of composite used, non-standardized methods of aging or storage time and the degree of scientific evidence obtained by the *in vitro* studies. Thus, more prospective studies are required to be done in a standardized procedure in the future for further research.

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## CONFLICT OF INTEREST

The authors declared there were no conflict of interest in conducting this study.

## ABBREVIATIONS

1. 10-MDP: methacryloyloxydecyl dihydrogen phosphate;
2. 4-MET: 4 methacryloxyethyltrimellitate anhydride;
3. ABU: All-Bond Universal;
4. AU: Ambar Universal;
5. Bis-GMA: Bisphenol glycidyl methacrylate
6. CAD/CAM: Computer-aided design/computer-aided manufacturing
7. CQ: camphorquinone;
8. CU: Clearfil Universal Bond;
9. D3MA: decandiol dimethadrylate;
10. FLD: Fusio Liquid Dentin
11. GPB: G-Premio Bond;
12. GPDM: glycero-phosphate dimethacrylate
13. HEMA: 2-hydroxyethylmethacrylate;
14. ISO: the International Organization for Standardization
15. LASER: Light amplification by the stimulated emission of radiation
16. MCAP: methacrylated carboxylic acid polymer;
17. MEPS: Methacryloyloxyalkyl thiophosphate;

18. NL: Nanoleakage;
19. OCU: One Coat 7 Universal;
20. PENTA-P: dipentaerythritol penta acrylate monophosphate
21. PRISMA: Preferred reporting items for systematic review and meta-analysis
22. SE: Self-etch;
23. SEM: Scanning electron microscope;
24. SU: Scotchbond Universal/ Single-Bond Unversal;
25. TBU: Tetric Bond Universal;
26. TE: Total-etch;
27. UDMA: urethanedimethacrylate;
28. VF: Versatile Flow;
29. μTBS: microtensile bond strength

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