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RESEARCH ARTICLE – DENTISTRY (MISCELLANEOUS)

Cantilever Extension for Implant-Supported Fixed Dental Prostheses: A Systematic Review

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Abstract

Background: Extend fixed dental prostheses (FDPs) with cantilever extensions used over locations with insufficient bone to avoid bone grafting. Cantilever extensions in both full-arch and short-span bridges have been documented in recent comprehensive reviews. However, cantilever FDPs have been the topic of numerous complaints of technical and mechanical issues. Therefore, this article addressed numerous variables to be analyzed in terms of implantation success rate, prosthesis success rate, minor bone loss, mechanical and technical prosthesis problems, and biological complications. Other variables from *in-vitro*, in-silico, and *in-vivo* studies were searched for and described where they were present, in addition to the loading duration of the rehabilitations, resources for reconstruction, and implant system used.

Objective of study: The present literature review aims to explore the use of cantilever-extending design as a successful treatment in implant-supported restorations for posterior regions.

Results: A Google Scholar operator scanned the literature and ran a hand search of the leading implantology and prosthetics journals from 2003 to July the 11th, 2023. Only articles on cantilevers for posterior implant-supported fixed restorations were considered. The outcome factors were implant and prosthetics survival, mechanics, technical, and biology issues, and bone loss on the margins. To better understand the implant-supported restoration with the cantilever extension approach and to assess its viability and dependability in the field of dental implants, this review article will focus on studies conducted over the past 20 years, beginning in 2003 to 2023. Therefore, this literature review aims to examine how the cantilever extension idea has been used in the field of dental implantology.
Conclusion: Thirty papers of cantilever extensions for implant-retained FPDs were chosen. The estimated *in-vitro* of 4 papers (14%), in-silico of 8 papers (27%), and *in-vivo* studies were of 17 papers (59%). There is a suggestion that cantilever extension can be an effective therapy in implant-supported restorations for posterior regions.

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Keywords: Fixed Partial Denture; Implant-Supported; Cantilever; Extension Design; Restoration.

1. Introduction

Despite the low survival rate of extended fixed partial dentures (FPDs), many dentists have been using them for years due to patient demand [1]. The predicted failure rate for a cantilever FPD after 10 years is 18.2%. Common biomechanical and technical failures that can occur at this period include a broken abutment crown or root a loosened abutment crown, and FPD fractures [2]. Most dental issues go undiagnosed until the pulp becomes painful, such as with cavities or a damaged tooth. Mechanical elements, the high rate of failure of cantilever FPD is mostly due to the conflict between mechanical considerations such as load transmission, and biological considerations such as periodontal health.

The artificial tooth in a cantilever fixed partial denture is anchored to the bridge only on one side, by the teeth or the implant. By eliminating the need for costly and sometimes dangerous bone augmentation, implant-supported cantilever restorations permit rehabilitation and reduce expenses. From a biomechanical standpoint, the cantilever arrangement may play a significant role in determining the process by which forces are transmitted between the bone and the implant. If cantilever extensions were used, more load-induced stress/strain could be concentrated near the implants. Despite previous research findings that cantilever extension may not compromise peri-implant bone stability; clinical testing and perception indicated that the cantilever design of a fixed partial denture could not be induced in subjects with a history of teeth grinding (bruxism) or improper bites (malocclusion) [3]. The use of end-abutment fixed dental prostheses (FDPs) is constrained by the private anatomical and biological characteristics of each patient. Besides the obvious clinical uses. The cantilever fixed dental prostheses (cFDPs) concept has many benefits. Fixed dental prostheses with cantilever fixed dental prostheses (cFDPs) of the posterior area can usually be accomplished by placement implants in the premolar area, as a result, invasive augmentation techniques. Possible alternatives to maxillary sinus floor elevation and posterior jaw bone grafting, reducing the size of the operating room and the time it takes to complete the procedure. Potential added benefits include a shorter treatment time and reduced cost. In this situation, most patients are fine with the idea of a shorter dental arch when it comes to treatment using tooth- or fixed dental prosthesis supported by implants with a cantilever. Aesthetically, fixed dental prosthesis supported by an implant with a cantilever (cFDPs) can be used to address issues such as inadequate combination of a horizontal bone structure and adverse biological traits [3].

In addition, patients may not be able to afford treatment if it requires two single implants with crowns. One implant with a single crown extended by a mesial or distal cantilever may be able to solve all of the aforementioned issues. However, there is a potential for technical and biological difficulties associated with this type of construction if the implant and superstructure are overloaded [4]. Computer-aided design and computer-aided manufacturing (CAD/CAM) and finite element modelling (FEM) and analysis (FEA) are two further examples of technological progress that have helped. Recent advances in the biomechanical field have boosted the usage of validated FEA research. FEA validations are classified into two types: (1) direct validation, which includes experiments on the quantities of interest (ranging from basic material characterisations to categorized system analysis, such as model experiments and in vitro experiments), and (2) indirect validation, which includes the use of literature or the findings of prior clinical studies. Given its precarious experimental quality, sources of error, and high level of unpredictability, indirect validation is less desired than direct validation. However, the majority of FEA examinations of force distribution may not be related to any specific biological consequence, making indirect validation in FEA unavoidable. As a result, producing outcome data for comparison with other studies is difficult [5].

Several technique-sensitive, time-consuming, and costly steps go into the creation of high-quality restorations. The posterior teeth like molars and premolars should have FPDs that can resist the stresses of chewing without breaking. This is crucial for the biofunctionality of the posterior restorations, which are largely made for mastication function rather than aesthetics [6].

Reconstructing undented ridges close to implants using cantilevers or pontics is a straightforward and cost-effective option. A cantilever fixed partial denture (CFPD) restoration is anchored at one end by an abutment or abutments but freestanding at the other end. Earlier mechanical research showed that dental implant-supported cantilever fixed dental prostheses (cFDPs) could provide a high concentration of stress in the alveolar bone, which could lead to bone resorption under occlusal pressures, particularly in the cervical region of implants. Stress division within acceptable duration to the supporting bone and related components is crucial for cantilever fixed partial dentures (CFPDs), so understanding the link between biology and mechanics is essential [7].

To further secure the cantilevered portion, many experts suggest inserting an implant or implants [8-14]. Using biological and mechanical considerations in case selection, implant site, and prosthesis design can more evenly distribute masticatory forces and prolong the life of the abutment [13, 15]. Thus, the present study aimed to explore whether cantilever extension for the last two decades could be a successful treatment in implant-supported restorations for posterior regions.

2. Materials and Methods

A Google Scholar operator scanned the literature (Google Scholar) and ran a hand search on the leading implantology and prosthetics journals from 2003 to July the 11th, 2023. Only articles on cantilevers for fixed restorations supported by implants in the posterior jaw were examined. The outcome factors were implant and prosthetics survival, mechanics, technical, biological issues, and bone loss on the margins.

To better understand the implant-supported restoration with the cantilever extension approach, this review research will focus on studies over the past 20 years starting in 2003 to evaluate its viability and usefulness for use in the field of dental implants.

2.1. Research for cantilever implant-supported fixed partial denture

In the past two decades, many researchers conducted the use of cantilevers in their publications in connection to implant dentistry.

2.1.1. The in-vitro and in-silico studies

Rehabilitation with permanent fixation using implants might be problematic because of the patient's features structure and form characteristics, which influence implant selection and distribution. This is an important consideration in the design of prosthetic structures. The cantilever length, shape, and angle are significant aspects to consider in fixed implant rehabilitations, specifically rehabilitations with structures containing cantilevers because they determine the rehabilitation's longevity. Table 1 summarizes *in-vitro* and in-silico studies for the past two decades concerning cantilevers in connection to implant-supported fixed restoration.

Table 1. In-vitro and in-silico studies related to implant-supported cantilever fixed dental prostheses (FDPs)

Author	Study Variable	Conclusion
[7]	Evaluation of the influence of two different implant collars (micothread and non-micro thread collars) that reinforced the models on stress application (300N vertical, 150N oblique, 60N horizontal) on the bone surrounding implants by using Finite element analysis.	Higher stress was had in the cancellous bone and framework of the collar with a microthread structure than in the collar without microthread structure models. The application of stress in cantilever fixed partial restorations was related to implant collars and load direction.
[8]	The effect of different four implants' inclinations (0º, 15º, 30º, and 45º), and cantilever lengths (13, 9, 5, and 0) mm in the maxillary digital model on load distribution (150N vertically).	Maximal stress was (75.0MPa) distally, (35MPa) mesially, and (95MPa) (metal framework). Distal implant inclined reduces stress for all the variables (12.9%, -18.3%, and -11.5% for the 15º design; -47.5%, -52.6%, and -31.3% for the 30º design; and -73.5%, -77.7%, and -85.6% for the 45º design. Using finite element analysis reduces stress in both framework and bone.

Continue Table 1. In-vitro and in-silico studies related to implant-supported cantilever fixed dental prostheses (FDPs)

[16]	Single Astra Tech diameter implant (4.0 or 5.0 mm) support for two-unit cantilever bridges was constructed as a single piece of porcelain and precious metal, and retention by a direct screw to keep them in place. Used maxilla or mandible edentulous space (equal to two bicuspid units) in premolar or molar region.	After receiving treatment, The main problem was the abutment screws loosening common occurrence. Both the radiographic bone height and bone levels on the cantilever and noncantilever sides of the implant remained stable. A cantilever-fixed dental prosthesis bridge can be supported by a single implant successfully.
[17]	A digital model of the maxilla with the absence of two central incisors was created with two-piece fixed partial dentures, either cantilevered or non-cantilevered. An algorithm for adjusting the strain energy density was used to simulate the remodelling of bones numerically, This includes the bone resorption procedure being too active.	The cantilever and free-cantilever designs were evaluated in terms of quantitative and qualitative bone responses to normal and overload conditions. Stress from machinery and stress division was also analyzed. The predicted values were also in contrast to those obtained from a radiograph of the surgical site to ensure accuracy. Under loading function, the cortical neck around the implant-supported cantilever fixed partial denture suffered less bone resorption than the non-cantilever fixed partial denture design.
[18]	A 3-dimensional finite element analysis is used for the comparison between two different implant designs and two different restoration materials of 3-unit implant-supported fixed cantilever restorations to decrease the stress around bone and implant (150N occlusal load).	Both restoration materials showed almost similar distribution and a magnitude of stress. The higher stress focuses on the ITI® implant where the conventional metal porcelain restoration is attached. While the AstraTech microthread design distributes stress more evenly, it is still concentrated at the implant neck.
[19]	Evaluation of Fracture strength of cantilevered zirconia frameworks, change in effective connector site cross-sectional area, and zirconia implant frameworks with varying cantilever lengths (load points). A distal cantilever measuring 12mm in length was split into four groups (n=10). Connector sizes (3×5)mm, (3×4)mm, and cantilever loading distances (7mm, and 10mm).	This study used two-way ANOVA statistical analyses to analyse the fracture force of the designed connector and they found that the fracture was affected significantly by the connector length and dimension. The largest deviation from theoretical predictions was found for the 7 mm (3×5) mm group in the Static Cantilever Design. The majority of zirconia frameworks failed due to fracture, while abutment screws and implant analogues remained in good shape. Higher loads caused zirconia implant frameworks with 3×5mm connector dimensions to fracture more than those with 3×4mm connector dimensions.
[20]	Evaluation of cantilever length and anteroposterior expansion full-mouth dental implants fixed with metal and resin in the mandible restoration and maxillary complete removable dental restoration. For all the patients received in this study must measure their cantilever length and anteroposterior expansion to assess potential complications (determined by casting them in polyvinyl siloxane), The screw became loose or broke, and/or the metal framework cracked. Based on cantilever length and posterior spread, a logistic regression analysis was used to assess the AP spread ratio between the two groups (>2.1 and 2.1), and different breakdowns by age, cantilever length, and right/left cantilever length.	By use of linear regression analysis, no statistically significant relationship between cantilever length, age, and anteroposterior proportion and the total quantity of defeat, The Group with an anteroposterior spread ratio >2.1 did not have a higher rate of complications than the group with a anteroposterior spread ratio of 2.1. The previous factors are not significantly associated with screw-related complications. Mandibular metal resin implant fixed complete dental restoration may have a lower incidence of screw-related complications compared to maxillary complete denture situations.
[21]	Comparison of the performance of cantilever restoration with and without a glass abutment. Using the maxillary digital model with cantilevered bridges, The finite element test was done with ANSYS. Skyscan 1173 was used to evaluate how well it fits, and how much space is between the glass abutment and the model.	Under vertical and oblique loads, the glass abutment-supported cantilever prosthesis deformed far less and demonstrated reduced stress on the terminal abutment. The ridge's mucosa is kept healthy by the glass abutment's passive contact, and the abutment can be cleaned easily. Glass abutments increase the probability of prosperity for cantilever FPDs.
[22]	Examining the effect of cantilever extent and alloy framework on load division in cantilevered fixed implant-supported partial restorations. Two implants (3.75 mm) were placed into a polyurethane mould in the form of a U-shape to represent the mandibular jaw bone. structure of the alloy (CoCr or PdAg), 300N load, and the load point distribution (5mm, 10mm, and 15mm of cantilever arm).	Using a two-way ANOVA analysis and Tukey's test, found statistically significant between the groups. Pearson's test showed a positive correlation between peri-implant region deformation and cantilever arm extension. The CoCr alloy shows a higher compression level than the PdAg alloy for both cantilever lengths. The load point distribution affects the distortion of the peri-implant region, which increases with the length of the arms level.

Continue Table 1. In-vitro and in-silico studies related to implant-supported cantilever fixed dental prostheses (FDPs)

[23]	Evaluation of the effect of various cantilever lengths and connection methods (external hexagon [EH] or Morse taper [MT]) on the stress division of implant-supported restoration. Two screws were used to secure crowns to implants, and Photoelastic resin was used to create three models. Several cantilever crowns (single or double). The implant restoration piece was studied with a polariscope in a circular fashion. 100N loads were applied in the axial and oblique (45º) directions.	A digital program was used to record and analyze data. All groups had the same fringe numbers that were comparable across groups when loaded axially but increased when loaded obliquely. The distribution of stresses under axial loading was significantly influenced by cantilever length but not by the implant connection system.
[24]	Effects of mesial or distal cantilever placement and external hexagonal or morse taper implant connection) on the stability of implant-supported zirconia fixed partial restoration. Tomographic slices of the posterior mandible were used to create four models with partial zirconia crowns, bridge, and screw restoration. The load application was 100N vertically for the premolar and 300N for the molar to estimate the distribution of loads in implants screw, abutment, and bone type (both cancellous and cortical), it is necessary to simulate the occlusal load in every model.	The cortical compression increases in external hexagon (EH) connection than morse taper (MT). The location of the cantilever in the molar region also increases the cortical compression and stress concentration. Among the many methods tried to restore the posterior mandible, the combination of a Morse taper implant and a mesial cantilever proved to be the most reliable.
[4]	Posterior two-unit with - implant-supported fixed cantilever dental restoration. For the period from January 2004 to February 2018 of use of implants and fixed restoration, the presence of outer bone marrow, the Plaque status and calculus, bleeding upon examination, the condition of the mucosa, the probing depth of the pockets, and the patient's level of satisfaction were all recorded.	23 patients and 28 implants were included in the study, and the average duration of observation was 6.5±4.8 years. In terms of durability, the fixed partial dentures and implants were an unqualified success. With stabilized peri-implant bone plane, minimal Problems with the technology, and very satisfied patients, mesial or distal cantilever fixed partial dentures supported by a single implant may be predictable of treatment in the back. However, peri-implantitis and peri-implantitis were very common.
[6]	Fracture load analysis of Zirconia frameworks supported by CAD/CAM cantilever implants. Used different dimensions of cross-sectional connector sites, and then sorted into 4 groups according to cantilever extent and distal-abutment enforcement: Cantilevers of Group A (9mm), Group B (9mm) with enforcement distal-abutment, Group C (12mm), and Group D (12mm),(n=12) with a strengthened distal abutment. With the aid of a standardized testing device.	The load fracture differed significantly amongst the four cantilever implant-supported zirconia frameworks. The cantilever length and lateral abutment thickness had a substantial effect on the cantilever zirconia implant frameworks and their corresponding fracture loads. By increasing the thickness of the distal abutment by merely 0.5mm, the fracture load of the cantilever implant-supported zirconia frameworks is considerably increased.
[3]	Examination of Continuity of Life and Complications of cantilever zirconia and metal-supported fixed dental restoration (anterior and posterior). In this retrospective study, the results of implant-supported non-cantilever full-arch dental prostheses and experimental implant-supported cantilever full-arch prostheses were compared over a mean observation period of 3.5 years. Over time, the two groups' survival and success probabilities were compared using estimates derived from the Kaplan-Meier method.	After 5 years, the total years of life until recovery is lost for cFDPs was 97.1 % and for ncFDPs, it was 97.0%. Ceramic fused to metal vs. non-ceramic fused to metal (cFDP vs. ncFDP; pLog=0.002), all-ceramic vs. metal structure (pLog 0.001), and temporary vs. final cement (pLog=0.025) all yielded different results. The retention loss was the most common problem with both traditionally and unconventionally cemented FDPs.
[25]	Fixed dental restoration supported by zirconia implants, specifically cantilever bridges. Two-unit implant fixed dental restoration (n=60) was premolar connectors can be either 9 or 12 mm^2 in size, and zirconia disks can be inserted into either the tooth's enamel or dentin. The force exerted on the teeth during the chewing simulation was measured and analyzed.	The implant cantilever fixed dental restoration and the implant did not break during the aging simulation. The mean fracture loads for a 9mm^2 connector (951N) were much greater than those for a 12mm^2 connector (638N). More implant fractures happened through an increase in the fracture load values from 751 to 838N for use with zirconia. With improved flexibility in two dimensions. To lessen the possibility of breakage along the intraosseous implant, designers of implant cantilever fixed dental restoration on zirconia implants should account for a weaker zirconia material and a smaller 9mm^2 connection.
[26]	Used a three-dimensional analysis to evaluate the effectiveness of ultra-short implants that support inter-foraminal implant placement techniques in the posterior region (screw retained). We use a 4mm implant in the posterior region. Use 3-D finite element analysis.	The presence of posterior implants that are extremely short decreases technical complications and risk, especially in high-risk cases like bruxism.

Continue Table 1. In-vitro and in-silico studies related to implant-supported cantilever fixed dental prostheses (FDPs)

[27]	Evaluation of the connection between various implant diameters (small diameter and standard diameter) and various cantilever lengths in maxillary implant-supported restoration on bone lack. Cone Beam Computed Tomography was used to evaluate the bone level changes at 4, 8, and 24 months post-treatment.	Both implant diameters and cantilever lengths affect the bone level change of maxillary implant-supported restoration.

The use of cantilever and free-cantilever designs restricted the quantitative and qualitative bone responses under normal and overload conditions. The bone around the implant-supported cantilever fixed partial denture seems to suffer less bone resorption than the non-cantilever fixed partial denture design. Therefore, the more use of terminal cantilevers, the less stress under the loading function.

2.1.2. The in-vivo studies

To prevent bone grafting in cases where there is insufficient bone, fixed dental prostheses (FDPs) have been extended using cantilever extensions. Cantilever extensions have been recorded in both full-arch and short-span bridges, although only rarely as part of a single implant-supported prosthesis. Cantilever-fixed dental prostheses (cFDPs) have been the subject of numerous reports of technical and mechanical problems in recent systematic evaluations. Therefore, the following, Table 2 summarizes the studies related to the cantilever with different parameters for the last two decades.

Table 2. The in-vivo studies related to cantilever extensions for fixed dental prostheses (FDPs)

Study	**Design**	**Follow up**		**Implant (mm)**		**Prosthetic**				**Complications (Prosthesis)**
		Year	**Month**	**Diameter**	**length**	**Retention**	**Material**	**Loading**	**Cantilever/ location**	
[28**]**	Prospective	3	9	3.3-4.1	10-14	Cement-/screw-retained	Gold-porcelain	≥ 3 months	34 mesial, 15 distal	Abutment loosening (1)
[29**]**	Retrospective	5	-	3.5	8-19	Screw-retained	Occlusal porcelain	7 months maxilla, 4 months mandible	16 maxilla, 8 mandible	Screw loosening (3), ceramic fracture (3)
[30]	Prospective	10	-	N/A	N/A	Cement-/screw-retained	Metal-ceramic	3-6 months	17 mesial, 36 distal	N/A
[31]	Prospective	5	-	N/A	N/A	Screw-retained	Metal-ceramic	N/A	N/A	Ceramic fracture (4), screw fracture (1), screw loosening (2)
[32]	Retrospective	5	3	3.3-4.8	6-12	Cement-retained	Gold-porcelain	>6 weeks	13 maxilla, 14 mandible; 12 proximal, 15 distal	Decementation (1), chipping (4)
[10]	Prospective	8	2	≥ 3.3	≥ 8	Screw-retained (13) prostheses , cement-retained (46) prostheses	Gold-porcelain	>3 months	32 mesial, 27 distal; 33 maxilla, 26 mandible	Decementation (3), veneer fracture (17)
[33**]**	Retrospective	5 and 2	65 and 48	4.1 or 4.8	N/A	Cement-/screw-retained	Metal-ceramic	>3 months	9 mesial, 12 distal; 14 maxilla, 7 mandible	0
[33]	Retrospective	6 52	2 and 88	4.1 or 4.8	N/A	Cement-/screw-retained	Metal-ceramic	3-6 months	9 mesial, 10 distal; 5 maxilla and 14 mandible	0
[34]	Retrospective cohort	4	3	3.3-6.0	7-25	N/A	N/A	8-12 weeks	71 mesial, 61 distal; 84 maxilla, 39 mandible	Prosthesis fracture (1), abutment loosening (9), abutment

Continue Table 2. The in-vivo studies related to cantilever extensions for fixed dental prostheses (FDPs)

[35]	Retrospective	10	-	3.3 (7 implants), 4.1 (44 implants), 4.8 (9 implants)	8-12	59 cement-retained; 1 screw-retained	Gold-porcelain	3-6 months	6 mesial, 21 distal, 3 distal and mesial; 23 maxilla, 7 mandible	Decementation (9), screw loosening (1), abutment fracture (1)
[36]	Retrospective	6	5	4.0	8-13	Screw-retained (19) prostheses cement-retained (9) prostheses	Metal or zirconia-based porcelain	12 weeks	23 mesial, 5 distal; 13 mandible, 15 maxilla	Decementation (1), screw loosening (1), veneer fracture (2)
[37]	Retrospective	13	6	4.1 (16 implants), 4.8 (9 implants)	8-12	Cement-retained	Metal-ceramic	3-6 months	16 mesial, 9 distal; 15 mandible, 10 maxilla	Chipping of ceramic (2), decementation (3), screw loosening (2)
[38]	Randomized clinical trial	5	-	4.1	6	Screw-retained	Metal-ceramic	3-6 months	Mesial, mandible	Chipping or screw loosening (4)
[3]	Retrospective	5 to 10	-	4.1mm	10mm	Glass-ionomer or zinc-oxide definitive cement. Or attached using adhesive cement or screw-retaining.	High-nobility metal alloys, such as cobalt-chromium (CoCr) and zirconia [39].	A delayed loading from 3 months after implant placement in the mandible to a maximum of 9 months in the maxilla	More cantilevers were distal than mesial.	Loss of retention followed by chipping
[25]	Retrospective	10 to 15	-	4.1mm	12mm	Cement	Metal-ceramic or zirconia	Difference between the $12mm^2$ (638N) connector and the $9mm^2$ (951N) connector	Mesial cantilever	Fractures and chippings
[26]	N/A	-	-	4.1mm 4.1mm	12mm 4mm	Screw-retained	Titanium sub-structure	A dynamic 100N occlusal force	20 mm cantilever between the prosthetic	Additional and complex surgical procedures, additional costs, and prolonged healing periods
[27]	Retrospective	-	4, 8 and 24	Small diameter (3.0mm)	Height 13 mm for the anterior implants	Screw-retained	A mixture of amalgam powder	Randomized Controlled Trial	Distal cantilever	The cantilevers in implant-supported prostheses

Recently, mesial and distal cantilevers have found a new use and application in implant-supported prostheses. Sites, where the maxillary sinus, neighbouring tooth roots, or inferior alveolar nerves make traditional implant insertion difficult, can benefit from cantilevers used in implant dentistry. Additional occluding units given by the cantilever section may allow for improved functionality and aesthetics. Cantilevers, on the other hand, have the potential to disrupt the biomechanics of implant restorations, resulting in mechanical and/or biological difficulties. Because the lower alveolar nerve and the maxillary sinus are protected by the cantilever, graft surgery is not as often required. Cantilever prostheses' altered biomechanics can increase the likelihood of technical and biological difficulties such as loss of retention, infrastructural fracture, porcelain veneer fracture, screw loosening or fracture, and peri-implant bone loss. The type of implant connectors is also an important factor in determining treatment outcomes. As a result, more laboratory and clinical research on the usage of terminal cantilevers were required. This is critical for the biofunctionality of posterior restorations, which are primarily intended for functionality rather than aesthetics.

3. Discussion

To explore whether cantilever extension can be a successful treatment in implant-supported restorations for posterior regions a systematic review was conducted, multiple studies have investigated cantilever extension uses in the context of cantilevers in connection to implant-supported fixed restoration, as shown in Table 1. In the same regard, other studies explored the context related to the cantilever with different parameters for the last two decades, as shown in Table 2. Accordingly, a study by [27] from Cairo University conducted a study to evaluate the changes that occurred in the supporting components of the implants placed in the maxillary as a result of combining two sets of dimensions- implant diameter and Cantilever length, found that both the standard and small implant diameter with different cantilever length showed marginal bone height changes within the physiologic limit for implant-supported maxillary prosthesis. Furthermore, [7] stated that higher stress was had in the cancellous bone and framework of the collar with a microthread structure than in the collar without microthread structure models. The application of stress in cantilever fixed partial restorations was related to implant collars and load direction. Also, [17] found that under loading function, the cortical neck around the implant-supported cantilever fixed partial denture suffered less bone resorption than the non-cantilever fixed partial denture design. The findings of [21] discovered that under vertical and oblique loads, the glass abutment-supported cantilever prosthesis deformed far less and demonstrated reduced stress on the terminal abutment. The ridge's mucosa is kept healthy by the glass abutment's passive contact, and the abutment can be cleaned easily. Glass abutments increase the probability of prosperity for cantilever FPDs.

Restoring lost teeth can be achieved through the use of various prosthetic designs. The use of two abutment teeth, one on each side of the edentulous area, to support FPDs is not always feasible. For cases like these, an FPD fitted with a distal cantilever can serve as a tooth replacement. According to [18], the highest equivalent stress in a fixed prosthetic device (FPD) with a central pontic is less than half that of a cantilever FPD and the cantilevered ends of the prosthesis places an additional strain on the initial implant closest to the cantilever arm. The tensions surrounding the implants are significantly affected by the cantilever length. Greater tension is exerted on the implants as the cantilever's length increases. Furthermore, [20] stated that >15 mm of cantilever length led to higher mechanical complications.

Using a cantilever lessens the likelihood of graft surgery and protects vital anatomical areas including the maxillary sinus and lower alveolar nerve. On the other hand, cantilevers alter the prosthesis' biomechanics, which can lead to a host of technical and biological issues, including retention loss, infrastructural fracture, porcelain veneer fracture, screw loosening or fracture, and peri-implant bone loss in particular. According to [23], the two primary forces acting on the implant are the axial force and the oblique force. Their research showed that under oblique loading, in particular, the stress rose as the cantilever length increased.

In the cohort, a study by [35] discovered a trend toward accelerated marginal bone loss at implant locations both close to and far from the cantilever extension. These results are comparable with those reported in a long-term retrospective cohort study. Accordingly, a study by [35] conducted a study to evaluate the changes that occurred in the fracture force between four groups for implant-supported cantilever zirconia frameworks (ISCZFs) that were used within the limitations of this study, it can be concluded that there were notable differences in the fracture load among the ISCZFs with varying cantilever lengths and distal abutment thicknesses. The fracture load of the ISCZFs is substantially raised when the distal abutments are reinforced by adding 0.5mm to their thickness. Concurrently, the fracture load of ISCZFs is dramatically reduced as the distal cantilever lengthens. It is advised to create distal cantilevers with the lowest length to guarantee the ISCZFs last a long time [6] The findings of [3] discovered that there was little difference in survival rates between the group given non-cantilever fixed dental prostheses (ncFDPs) and the one given cantilever fixed dental prostheses (cFDPs). This leads to the believe that cantilever FDPs supported by implants are a viable alternative for treating incomplete dentition, and their long-term survival rates are encouraging. According to the evidence stated in tables 1 and 2, and in regards to the cantilever extension, the significant majority were *in-vivo* successful treatment in implant-supported restorations that showed a promising therapeutic option.

4. Conclusions

According to this article's collected data, most investigators *in-vitro* and in-silico studies concluded in their studies that the presence of a distal cantilever seems to increase the concentration of stress on implants, prosthetic abutments, screws, and the bone-implant interface. However, *in-vivo* restorations supported by implants with cantilevers seem capable of supplying an acceptable success rate of prosthesis over 5 years (83%) with limited technical complications such as broken abutment crown or root a loosened abutment crown and FPD fractures. The rest of the studies (17%) suggested further clinical investigation for the applications of distal cantilevers with implant-supported restorations of different designs. One limitation of this study was that research of various designs (both retrospective and prospective research) was chosen and examined together. This was done to take into account the largest possible database for study, although it may have contributed to the datasets' heterogeneity.

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Nomenclature & Symbols			
FDPs	Fixed dental prostheses	EH	External hexagon
CFDs	Cantilever-fixed dental prostheses	MT	Morse taper
FEM	Finite element modeling	mo	Month
FEA	Finite element analysis	Wk	Week
CFPD	Cantilever fixed partial denture	N/A	Not applicable
CFPDs	Cantilever-fixed partial dentures	mm	Millimeter
MPa	Mega pascal	ITI®	DENTAL IMPLANT SYSTEM
N	Newton	Co-Cr	Cobalt-Chromium

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