Review

Survival Rate of Zygomatic Implants for Fixed Oral Maxillary Rehabilitations: A Systematic Review and Meta-Analysis Comparing Outcomes between Zygomatic and Regular Implants

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Abstract: Background: Zygomatic implants have been proposed alone or in combination with premaxillary conventional implants for severe resorbed maxillary atrophy rehabilitation. The aim of the present investigation was to evaluate through a qualitative systematic review and meta-analysis the survival rate of zygomatic implants in conjunction with regular fixtures for maxillary rehabilitation. Methods: The article screening was conducted on the PubMed/Medline and EMBASE electronic databases according to the “Preferred Reporting Items for Systematic Reviews and Meta-Analyses” (PRISMA) guidelines. The scientific papers were included for qualitative analysis and risk-of-bias evaluation. Only the papers that included rehabilitation with zygomatic implants in combination with regular implants were considered for the meta-analysis comparative evaluation of the implant survival rate. Results: The paper search screened a total of 137 papers. After the initial screening, a total of 32 articles were considered for the qualitative analysis. There was a similar implant survival rate between zygomatic and premaxilla regular implants ($p = 0.02; Z: 2.26$). Conclusions: Zygomatic and conventional implants showed a high long-term survival rate for fixed maxillary rehabilitations, but few included studies reported the marginal bone loss after loading. Further studies are necessary to evaluate the pattern of marginal bone loss between zygomatic and conventional implants after long-term functional loading.

Keywords: zygomatic implant; endosseous implants; bone ridge atrophy; maxillary fixed rehabilitations

1. Introduction

The rehabilitation of severely atrophic maxilla represents a complex treatment due to functional and aesthetic alteration related to tooth loss and extreme bone ridge resorption [1–3]. Moreover, the loss of masticatory and phonetic efficiency could produce important implications for social relationships and quality of life [4,5]. The positioning of implants to rehabilitate partial or total edentulous ridges represents a validated long-term treatment option, while the availability of adequate bone volume and density could determine a possible clinical limitation for implant fixation and loading [6–11]. The atrophies of the maxilla have been classified from Cawood–Howell Class I to Class VI [2]:

- Class I: teeth present.
- Class II: immediate post-extraction socket.
- Class III: edentulous ridge with adequate height and width of bone.
- Class IV: knife-edge ridge, adequate bone height but inadequate in width.
- Class V: flat bone ridge, bone inadequate in width and height.
- Class VI: depressed-form ridge, basal bone resorption.
According to local anatomy and sinus cavity dimensions, many different approaches have been proposed for maxillary rehabilitations with 4/6 tilted dental implants [12–15] in combination with single/bilateral zygomatic implants. These severe cases are often correlated in clinical practice after severe bone resorption, local infections and resective oncologic surgery [16,17]. Zygomatic implants have been proposed as a valuable treatment option for fixed rehabilitation in severe reabsorbed bone ridges due to the reduced invasivity, morbidity and decreased time required to finalize the rehabilitation [5,17,18]. Zygomatic implant positioning is an approach that avoids grafting or maxillary sinus augmentation and consequently produces a shorter and more comfortable post-operative morbidity [18–20]. In fact, the restoration of severe maxillary atrophies often requires an extensive grafting approach with autologous bone from a calvaria, iliac crest or mandibular graft with an higher surgical morbidity, cost of rehabilitation time and a reduced predictivity [21–23].

Other indications for zygomatic implants include the previous failure of conventional implant placement, failure of grafting procedures and tumor resection or trauma [4,12,17,24]. The zygomatic bone is a bilateral, pyramidal bone characterized by a cortical and trabecular component. Tomographic studies reported that no significant morphological and volumetric alterations of this region are associated with tooth loss and jaws atrophies while the zygomatic bone has a sufficient bone density and is a candidate for dental implant positioning [25–27].

Anatomically, the morpho-structural maintaining of this region is determined by the action of masseter muscles that induce constant bone remodeling stimulation and functional activity [27,28].

Maxillary rehabilitations with four bilateral zygomatic implants or in combination with two or more regular premaxillary implants have been successfully proposed for two-stage or immediate functional loading protocols [29–31]. The purpose of the present investigation was to compare the survival rate of combined zygoma maxillary and zygomatic implants in association with regular implants in the premaxilla through a systematic review and meta-analysis.

### 2. Materials and Methods

#### 2.1. Database Search Strategy

The PICO (population, intervention, comparison, outcome) question has been reported in Table 1.

| Population Patients | Intervention | Comparison | Outcomes |
|---------------------|--------------|------------|----------|
| Patient group of interest? | Zygomatic implant positioning for fixed maxillary rehabilitation. | Zygomatic implant vs. regular maxillary implant survival rate. | Can zygomatic implants provide a valuable survival rate for fixed rehabilitation in maxillary severe atrophies? |
| Subjects that need oral rehabilitation with zygomatic implant surgery in maxillary severe atrophies. | | | |

The paper’s search and inclusion and study data presentation were performed in accordance to the “Preferred Reporting Items for Systematic Reviews and Meta-Analyses” (PRISMA) guidelines [32]. The more appropriate medical search terms (MeSH) and keywords were identified by the Cochrane library to create a detailed search strategy (Table 2). The paper’s initial screening was conducted on the PubMed and EMBASE electronic databases (13 December 2020) according the Boolean search detailed in Table 2. The
Abstracts of scientific studies selected were limited to only human randomized and non-randomized clinical trials, prospective and retrospective studies with zygomatic maxillary rehabilitation and were selected for a full-text evaluation.

Table 2. Electronic database Boolean search: keyword strategy.

| Search Strategies                                      |
|-------------------------------------------------------|
| **Keywords:** Advanced keyword search: (zygomatic dental implant AND oral rehabilitation) AND (retrospective study OR prospective study OR controlled study) |
| **Databases**                                        |
| PubMed/Medline, EMBASE                              |

2.2. Inclusion and Exclusion Criteria

For the qualitative analysis, the inclusion criteria were human clinical trials, prospective and retrospective studies with a minimum follow-up of 6 months. The inclusion criteria were articles describing zygomatic implants for partial or full fixed maxillary rehabilitations with no restrictions on number of zygomatic and regular implants positioned or immediate/delayed loading protocol. The exclusion criteria were systematic reviews, letters to the editor, case reports and case series, in vitro and laboratory simulations and dental implants associated to a bone regeneration/sinus augmentation procedure.

2.3. Papers Selection Procedure

The selection of the research papers eligible for the qualitative analysis was performed independently by two reviewers to evaluate the studies’ titles and abstracts. Moreover, a manual search was performed to increase the pool of the studies eligible for full-text evaluation. The screening phase of the papers’ selection included clinical trials with no restrictions about randomization and blinding assessments in order to increase the item pool. The papers written in English that satisfied the inclusion criteria were included, and the full-text was obtained and evaluated. The duplicates and excluded papers were also recorded and categorized according to reasons of review exclusion.

2.4. Study Assessment

The study data of the selected papers were recorded and evaluated independently through a specially designed form according to the following categories: study model design, treated patients, number of zygomatic and regular implants, smokers, immediate or delayed zygomatic loading protocol, type of prosthesis, study follow-up, zygomatic and regular implant survival rate, complications and quantity of zygomatic implant failure.

2.5. Risk of Bias Assessment

The risk of bias assessment was performed by the software package RevMan 5.5 (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark, 2014). The risk of bias evaluation was according to the following parameters and criteria: randomization sequence, allocation concealment, blinding assessment, completeness of procedure description, clearness of inclusion criteria, attrition bias, reporting bias, follow-up length and other bias. The risk of bias criteria were categorized as adequate, unclear or inadequate. The selected studies were categorized as low risk of bias with a minimum ratio of 6/9 positive parameters and an absence of a negative outcome. Otherwise, the research was categorized as high risk.

2.6. Comparative Meta-Analysis

The research data were carefully analyzed through a special designed database in Excel (Microsoft, Redmond, WA, USA). The comparative meta-analysis of survival rate was performed including the clinical papers with zygomatic implants in combination with regular implants for fixed maxillary rehabilitations. No limits regarding follow-up, prosthesis typology, quantity of implants or patient characteristics were considered for the
evaluation. The means were considered for dichotomous data considering the number of implants with events and the total number of participants in experimental and control groups, while the survival rate of zygomatic implants compared to regular implant groups was considered the study outcome variable. The statistical comparison evaluated the survival rate of zygomatic implants positioned for anchorage in the zygomatic bone vs. regular dental implants positioned in the maxillary alveolar bone. Pterygoid implants, trans-sinus implants and implants positioned in the vomer/nasal crest have been excluded from the present evaluation.

3. Results

3.1. Paper Selection Process

The manuscript identification, screening, eligibility and inclusion process is presented in Figure 1. The total output list retrieved a total of 137 manuscripts: 106 were identified through the electronic search and 31 were selected by a manual search. After a title and abstract evaluation, a total of 97 manuscripts were excluded after the screening phase, and 40 papers were included for full-text evaluation. A total of 8 full-text papers were excluded: 3 literature reviews, 4 manuscripts that were out of topic and 1 case report. A total of 32 papers were included for the qualitative synthesis [33–64], and 27 articles were considered for the meta-analysis [33–46,48,50,51,53–57,59–61,63,64].

![Figure 1. Summary of the manuscript selection process according to the “Preferred Reporting Items for Systematic Reviews and Meta-Analyses” (PRISMA) guidelines.](image)

3.2. General Property of the Studies Included

The articles were described according to the zygomatic implant positioned for each rehabilitation, type of prosthesis, follow up time, implant survival rate, surgical complications and zygomatic implants failed. The main characteristics of the studies included were described in Tables 3 and 4 according to study model, patients, number of regular and zygomatic implants, loading, prosthetic rehabilitation, study outcome and follow-up time. A total of 17 retrospective studies and 15 prospective studies were retrieved from the search.
Table 3. Summary table of the papers included for the qualitative evaluation.

| Authors          | Year | Journal                    | Zygomatic Implant Configuration | Prosthesis               | Follow up       | Zygomatic-Regular Implant Survival Rate | Complications                                      | Zygomatic Implant Failure |
|------------------|------|----------------------------|---------------------------------|--------------------------|----------------|----------------------------------------|-----------------------------------------------------|--------------------------|
| Agliardi et al.  | 2017 | Int J Oral Maxillofac Surg | Double (9)                      | Full-arch (15)-Partial (0)| 79 m to 97 m   | 100%-/-                                | -                                                  | -                       |
| Ahlgren et al.   | 2006 | Int J Oral Maxillofac Implants | Double (13)                    | Full-arch (13)-Partial (0)| 11–49 m       | 100–100%                               | -                                                  | -                       |
| Aparicio et al.  | 2010 | Clin Implant Dent Relat Res | Single (4)                      | Full-arch (20)-Partial (0)| 36–48 m       | 100–100%                               | -                                                  | -                       |
| Aparicio et al.  | 2010 | Clin Implant Dent Relat Res | Single (7)                      | Full-arch (69)-Partial (0)| 60 m          | 100–99%                                | Sinusitis                                           | -                       |
| Aparicio et al.  | 2010 | Clin Implant Dent Relat Res | -                               | Full-arch (23)-Partial (2)| 24 m to 60 m  | 100–99.2%                              | Regular implant failure (1), Abutment screw fracture (5) | 1 implant               |
| Aparicio et al.  | 2014 | Clin Implant Dent Relat Res | Single (3)                      | Full-arch (22)-Partial (0)| 120 m         | 95.12–97.71%                           | -                                                  | 2 implants              |
| Balshi et al.    | 2009 | Int J Oral Maxillofac Implants | -                              | Full-arch (56)-Partial (0)| 9–70 m        | 96.37–97.2%                            | Osseointegration failure                             | 4 implants              |
| Becktor et al.   | 2005 | Clin Implant Dent Relat Res | Single (1)                      | Full-arch (16)-Partial (0)| 9–69 m        | 100%                                   | Sinusitis                                           | -                       |
| Bedrossian et al.| 2006 | Int J Oral Maxillofac Implants | Double (14)                    | Full-arch (14)-Partial (0)| 6 m           | 100–100%                               | -                                                  | -                       |
| Bedrossian et al.| 2003 | Int J Oral Maxillofac Implants | Double (22)                    | Full-arch (22)-Partial (0)| 34 m          | 100–91.25%                             | -                                                  | -                       |
| Butura et al.    | 2014 | Int J Oral Maxillofac Implants | Single (1)                      | Full-arch (15)-Partial (0)| 24 m          | 100–100%                               | -                                                  | -                       |
| Chana et al.     | 2018 | Int J Oral Maxillofac Implants | -                               | -                        | 216 m         | 94.32%                                 | Sinusitis, implant mobility, pain                    | 5 implants              |
| Authors          | Year | Journal                        | Zygomatic Implant Configuration | Prosthesis           | Follow up | Zygomatic-Regular Implant Survival Rate | Complications                                                                 | Zygomatic Implant Failure |
|------------------|------|--------------------------------|---------------------------------|----------------------|-----------|----------------------------------------|-------------------------------------------------------------------------------|--------------------------|
| Coppede et al.   | 2017 | Clin Implant Dent Relat Res   | Single (6), Double (27), Triple (3), Quad (6) | Full-arch (42)-Partial (0) | 36 m      | 98.9–97.7%                            | Osseointegration failure                                                     | 1 implant               |
| Davò et al.      | 2018 | Eur J Oral Implantol           | Double (6), Quad (29)           | Full-arch (35)-Partial (0) | 12 m      | 96.1–91.6%                            | Sinus membrane perforation (4), major swelling (1), sinusitis (4), implant mucositis (2), Peri-orbital infection and swelling (2) | 5 implants/3 patients    |
| Davò et al.      | 2013 | Eur J Oral Implantol           | -                               | Full-arch (37)-Partial (5) | 60 m      | 98.5–94.9%                            | Osseointegration failure, peri-implant mucositis                               | 1 implant               |
| Davò et al.      | 2010 | Eur J Oral Implantol           | Quad (17)                       | Full-arch (17)-Partial (0) | 12 m      | 100–100%                              | Eye orbit drill penetration, fistula                                          | -                       |
| Davò et al.      | 2008 | Eur J Oral Implantol           | Single (5), Double (35), Quad (2) | Full-arch (37)-Partial (5) | 12-42 m   | 100–97%                               | Implant mobility                                                              | -                       |
| Davò et al.      | 2013 | Eur J Oral Implantol           | Quad (17)                       | Full-arch (17)-Partial (0) | 36 months | 100%-/                                 | Eye orbit drill penetration, fistula, sinusitis, fistula                      | -                       |
| Degidi et al.    | 2012 | Int J Periodontics Restorative Dent | Double (10)                  | Full-arch (10)-Partial (0) | 12 m      | 100–100%                              | Osseointegration failure, sinusitis, implant mobility, pain                   | -                       |
| Duarte et al.    | 2007 | Clin Implant Dent Relat Res   | Quad (12)                       | Full-arch (12)-Partial (0) | 30 m      | 97.91%                                | Sinusitis                                                                     | 1 implant               |
| Malevez et al.   | 2004 | Clin Oral Implants Res         | Double (55)                     | Full-arch (55)-Partial (0) | 6-48 m    | 100–91.75%                           | Sinusitis                                                                     | -                       |
| Authors            | Year | Journal                          | Zygomatic Implant Configuration | Prosthesis                  | Follow up | Zygomatic Regular Implant Survival Rate | Complications                                      | Zygomatic Implant Failure |
|--------------------|------|----------------------------------|---------------------------------|-----------------------------|-----------|----------------------------------------|---------------------------------------------------|--------------------------|
| Maló et al.        | 2014 | Eur J Oral Implantol             | Single (73)                     | Full-arch (352)-Partial (0) | 6–84 m    | 98.2–97.9                              | Sinusitis, implant mobility                        | 14 implants              |
|                    |      |                                  | Double (214), Triple (14), Quad (51), Single (8) |                            |           |                                        |                                                   |                          |
| Maló et al.        | 2015 | Clin Implant Dent Relat Res      | Double (18)                     | Full-arch (39)-Partial (0)  | 36 m      | 100–100%                               | Sinusitis, implant mobility, fistula               | -                        |
|                    |      |                                  | Triple (5)                      |                            |           |                                        |                                                   |                          |
| Migliorança et al. | 2012 | Int J Oral Maxillofac Surg       | Quad (8)                        | Full-arch (28)-Partial (0)  | 54 m      | 96%~                                 | Osseointegration failure                         | 4 implants               |
| Mozzati et al.     | 2008 | Int J Oral Maxillofac Implants    | Double (7)                      | Full-arch (7)-Partial (0)   | 24 m      | 100–100%                               | -                                                 | -                        |
|                    |      | Int J Oral Maxillofac Implants    |                                |                            |           |                                        |                                                   |                          |
| Neugarten et al.   | 2017 | Int J Oral Maxillofac Implants    | Quad (28)                       | Full-arch (28)-Partial (0)  | 54 m      | 96%~                                 | Osseointegration failure                         | 4 implants               |
|                    |      | J Oral Maxillofac Surg           |                                |                            |           |                                        |                                                   |                          |
| Pellicer-Chover et al. | 2016 | Med Oral Patol Oral Cir Bucal    | Double (22)                     | Full-arch (22)-Partial (0)  | 12 m      | 97.7–97.8%                            | -                                                 | -                        |
|                    |      |                                  |                                |                            |           |                                        |                                                   |                          |
| Petrunaro et al.   | 2020 | Compend Contin Educ Dent         | Single (134)                    | Full-arch (234)-Partial (15) | 60 m      | 97.6–97.7%                            | -                                                 | 11 implants              |
|                    |      |                                  | Double (79)                     |                            |           |                                        |                                                   |                          |
|                    |      |                                  | Quad (40)                       |                            |           |                                        |                                                   |                          |
| Sartori et al.     | 2012 | J Oral Maxillofac Surg           | Double (16)                     | Full-arch (16)-Partial (0)  | 48 m      | 100–100%                              | -                                                 | -                        |
|                    |      |                                  | Quad (3)                        |                            |           |                                        |                                                   |                          |
| Stiévenart et al.  | 2010 | Int J Oral Maxillofac Surg       | Quad (20)                       | Full-arch (20)-Partial (0)  | 6–40 m    | 96%                                  | Osseointegration failure, sinusitis, implant mobility, pain | 3 implants               |
|                     |      |                                  |                                |                            |           |                                        |                                                   |                          |
| Urgell et al.      | 2008 | Med Oral Patol Oral Cir Bucal    | Single (7)                      | Full-arch (54)-Partial (0)  | 48 months | 96.04–93.22%                         | Osseointegration failure, sinusitis, implant mobility, pain | 4 implants               |
|                    |      |                                  | Double (47)                     |                            |           |                                        |                                                   |                          |
| Zwahlen et al.     | 2006 | Int J Oral Maxillofac Implants    | Single (2)                      | Full-arch (18)-Partial (0)  | 8 m       | 94.1%~                               | Sinusitis, implant mobility, pain, fistula         | 2 implants               |
|                    |      |                                  | Double (15)                     |                            |           |                                        |                                                   |                          |
Table 4. Summary of the papers evaluated according to the study design, patients treated, zygomatic and regular screws positioned and implant loading protocol.

| Authors            | Year | Journal                  | Study | Patients | Zygomatic Implants | Regular Implants | Delayed Loading Zygomatic Implants | Immediate Loading Zygomatic Implants |
|--------------------|------|--------------------------|-------|----------|-------------------|------------------|-----------------------------------|--------------------------------------|
| Agliardi et al.    | 2017 | Int J Oral Maxillofac Surg | P     | 15       | 42                | 18               | -                                 | 47                                   |
| Ahlgren et al.     | 2006 | Int J Oral Maxillofac Implants | R     | 13       | 25                | 26               | 25                                | -                                    |
| Aparicio et al.    | 2010 | Clin Implant Dent Relat Res | P     | 20       | 36                | 104              | 36                                | -                                    |
| Aparicio et al.    | 2006 | Clin Implant Dent Relat Res | P     | 69       | 131               | 304              | 131                               | -                                    |
| Aparicio et al.    | 2010 | Clin Implant Dent Relat Res | R     | 25       | 47                | 129              | -                                 | 47                                   |
| Aparicio et al.    | 2014 | Clin Implant Dent Relat Res Int J Oral Maxillofac Implants | R     | 22       | 41                | 131              | 41                                | -                                    |
| Balshi et al.      | 2009 | Int J Oral Maxillofac Implants | R     | 56       | 110               | 391              | -                                 | 110                                  |
| Becktor et al.     | 2005 | Clin Implant Dent Relat Res Int J Oral Maxillofac Implants | P     | 16       | 31                | 74               | 31                                | -                                    |
| Bedrossian et al.  | 2006 | Int J Oral Maxillofac Implants | P     | 14       | 28                | 55               | -                                 | 28                                   |
| Bedrossian et al.  | 2003 | Int J Oral Maxillofac Implants | R     | 22       | 44                | 80               | 44                                | -                                    |
| Butura et al.      | 2014 | Int J Oral Maxillofac Implants | R     | 15       | 40                | 27               | -                                 | 40                                   |
| Chana et al.       | 2018 | Int J Oral Maxillofac Implants | R     | 45       | 88                | 180              | 88                                | -                                    |
| Coppede et al.     | 2017 | Clin Implant Dent Relat Res | P     | 42       | 94                | 179              | 16                                | 78                                   |
| Authors          | Year | Journal                          | Study | Patients | Zygomatic Implants | Regular Implants | Delayed Loading Zygomatic Implants | Immediate Loading Zygomatic Implants |
|------------------|------|----------------------------------|-------|----------|--------------------|------------------|----------------------------------|-------------------------------------|
| Davò et al.      | 2018 | Eur J Oral Implantol             | P     | 35       | 131                | 237              | -                                | 131                                 |
| Davò et al.      | 2013 | Eur J Oral Implantol             | P     | 42       | 81                 | 140              | -                                | 81                                  |
| Davò et al.      | 2010 | Eur J Oral Implantol             | P     | 17       | 68                 | -                | -                                | 68                                  |
| Davò et al.      | 2008 | Eur J Oral Implantol             | P     | 42       | 81                 | 140              | -                                | 81                                  |
| Davò et al.      | 2013 | Eur J Oral Implantol             | P     | 17       | 68                 | -                | -                                | 68                                  |
| Degidi et al.    | 2012 | Int J Periodontics Restorative Dent Clin Implant Dent Relat Res | P     | 10       | 20                 | 20               | -                                | 20                                  |
| Duarte et al.    | 2007 | Clin Oral Implants Res           | R     | 55       | 103                | 194              | 103                              | -                                   |
| Malevez et al.   | 2014 | Eur J Oral Implantol             | R     | 352      | 747                | 795              | -                                | 747                                 |
| Maló et al.      | 2015 | Clin Implant Dent Relat Res      | R     | 39       | 92                 | 77               | -                                | 92                                  |
| Migliorança et al.| 2012 | Int J Oral Maxillofac Surg       | P     | 21       | 40                 | 74               | -                                | 40                                  |
| Mozzati et al.   | 2008 | Int J Oral Maxillofac Implants    | P     | 7        | 14                 | 34               | -                                | 14                                  |
| Neugarten et al. | 2017 | Int J Oral Maxillofac Implants    | R     | 28       | 105                | -                | -                                | 105                                 |
| Pellicer-Chover et al. | 2016 | Med Oral Patol Oral Cir Bucal    | R     | 22       | 44                 | 94               | 44                              | -                                   |
| Petrungaro et al.| 2020 | Compend Contin Educ Dent         | P     | 249      | 452                | 360              | 249                              | -                                   |
Table 4. Cont.

| Authors          | Year | Journal                          | Study | Patients | Zygomatic Implants | Regular Implants | Delayed Loading Zygomatic Implants | Immediate Loading Zygomatic Implants |
|------------------|------|----------------------------------|-------|----------|--------------------|------------------|-----------------------------------|-------------------------------------|
| Sartori et al.   | 2012 | J Oral Maxillofac Surg           | R     | 16       | 37                 | 58               | 16                               | -                                   |
| Stiévenart et al.| 2010 | Int J Oral Maxillofac Surg       | P     | 20       | 80                 | -                | 40                               | 40                                  |
| Urgell et al.    | 2008 | Med Oral Patol Oral Cir Bucal Int J Oral Maxillofac Implants | R     | 54       | 101                | 221              | 101                              | -                                   |
| Zwahlen et al.   | 2006 | Int J Oral Maxillofac Implants   | R     | 18       | 34                 | 42               | -                                | 34                                  |
3.3. Study Characteristics and Risk of Bias Assessment

The patients’ recruited pool ranged from 7 to 352 subjects (mean: 44.68 ± 70.14) and 14–747 zygomatic implants (mean: 96.96 ± 140.85) positioned. The range of regular implants positioned was 18–795 screws (mean: 154.96 ± 163.26). The patients’ recruited pool ranged from 7 to 352 subjects (mean: 44.68 ± 70.14) and 14–747 zygomatic implants (mean: 96.96 ± 140.85) positioned. The range of regular implants positioned was 18–795 screws (mean: 154.96 ± 163.26). A total of 259 single zygomatic implant rehabilitations (mean: 18.50 ± 38.01), 798 double zygomatic implant rehabilitations (mean: 34.70 ± 43.32), 23 triple (mean: 5.75 ± 5.73) and 211 quadruple zygomatic implant rehabilitations (mean: 16.23 ± 15.36). A total of 1348 full-arch prostheses (mean: 43.48 ± 69.85) and 27 partial fixed prostheses (mean: 6.75 ± 5.68) were evaluated for the qualitative analysis.

The analysis of the risk of bias of the papers included is presented in Figure 2 for a total of 32 papers. A total of 5 papers were considered to have a low risk of bias (Figures 2 and 3) with a wide heterogeneity of study model design, type of rehabilitation and functional loading follow-up period. Davò et al. was the only randomized and blinded clinical study included for the qualitative evaluation and meta-analysis comparison [46].

![Figure 2](image-url)

Figure 2. Summary of the risk of bias assessment of the studies included.

3.4. Meta-Analysis Evaluation

After the qualitative analysis, a total of 27 articles were selected for the comparative evaluation of meta-data of the zygomatic vs. regular implant survival rate. For the meta-data evaluation, papers were considered with a minimum of 6 months follow-up with a zygomatic and regular implant-combined fixed rehabilitation. The minimum follow-up period of the selected paper was 6 months, and the maximum was 97 months. The analysis showed a significant overall effect \( p = 0.02; Z: 2.26 \); heterogeneity \( p = 0.20; \chi^2: 21.51, df: 1; I^2: 21\% \). The odds ratio (OR) was 0.67 (95 CI: 0.47–0.95) (Figures 4 and 5).
Figure 3. Details of the risk of bias assessment of the studies included.
3.4. Meta-Analysis Evaluation

After the qualitative analysis, a total of 27 articles were selected for the comparative evaluation of meta-data of the zygomatic vs. regular implant survival rate. For the meta-data evaluation, papers were considered with a minimum of 6 months follow-up with a zygomatic and regular implant combined fixed rehabilitation. The minimum follow-up period of the selected paper was 6 months, and the maximum was 97 months. The analysis showed a significant overall effect \( p = 0.02; Z: 2.26 \); heterogeneity \( p = 0.20; \chi^2: 21.51, df:1; I^2: 21\% \). The odds ratio (OR) was 0.67 (95 CI: 0.47-0.95) (Figure 4 and 5).

**Figure 4.** Forest plot of comparison between the zygomatic and regular implant survival rate.

**Figure 5.** Funnel plot of the zygomatic and regular implant survival rate comparison.

4. Discussion

The present investigation aimed to evaluate through a qualitative analysis the effectiveness and survival rate of regular vs. zygomatic implants for combined fixed maxillary rehabilitation in the literature through a meta-analysis. In the present study, a significantly higher survival rate of zygomatic implants vs. regular maxillary implant was present, while included papers showed a wide heterogeneity of study design, surgical protocols with or without bone graft and regeneration procedures and implant geometries. Reason-
ably, the survival rate of both regular and zygomatic implants could be influenced in a
decisive manner by all of the previously described factors. Moreover, the implant loading
protocols [8,65,66], the different sizes [67–70], prosthetic emergence profiles [71,72], the
number of zygomatic implants positioned [29,30], the different loading angle of zygomatic
compared to regular implants [28,43,73,74] and the quantity of keratinized tissues [75,76]
could represent key factors for the long term maintenance of soft and hard tissue lev-
els [38,77]. Moreover, the positioning localization of the implant screws could also play
an important role. In fact, the masticatory forces are dissipated in a more apical position
by the zygomatic implants at the level of the malar prominence of the maxillary bone if
compared to conventional screws, where they are discharged at the level of the maxillary
bone ridge at a functional distance from the aggression of bacteria biofilm adhesion and
infection risk factors present in the oral mouth [28,74].

Gümrükçü et al. investigated the biomechanics of bilateral zygomatic implant config-
urations for full maxillary rehabilitations, measuring the stresses and deformation of the
skull bone with a 150 N vertical occlusal and 300 N masseteric loading [74]. The authors
concluded that the maximum von Mises stress was reported in type 4 defects and D3 bone
types, while the minimum stress was reported in type 1 buccal bone defects and D2 bone
types [74]. In the literature, it was reported that an important role was determined by the
zygomatic bone support for the biomechanics and survival of zygomatic rehabilitation [28].
Romeed et al. reported that a residual zygomatic bone support of 10 mm was corre-
lated to a significant increase of zygomatic implant biomechanical stress [28]. The authors
evidenced that the zygomatic fixture deflection was lower than 2/3 times in the case of
zygomatic residual bone support of 15/20 mm [28]. Moreover, the study evidenced that
the von Mises stress (MPa) under occlusal loading was dissipated at the level of the bone-
implant interface and no significant difference were reported in the region of the abutment
prosthetic joint [28].

Zygomatic and regular implants showed survival rate ranges of 94.1–100% and
91.25–100%, respectively, while the most common early complications (<6 months from
the procedure) for zygomatic implant procedures were osteointegration failure, sinusitis,
Schneiderian membrane perforation, implant mobility, pain, eye orbit drill penetration and
oro-antral fistula (Table 2). Moreover, the literature has reported rare complications such
as aspergillosis associated to fungus contamination during the surgery and intracerebral
penetration, while a little error in the anf of the implant site preparation could deter-
mine an invasion of critical anatomic regions [30]. The delayed most common compication
represented is essentially the sinusitis that could occur years after the surgery [30].

Few articles screened additionally reported the marginal bone loss values around
zygomatic and regular implants [33,45]. Agliardi et al. reported on nine full restorations
with double bilateral zygomatic implants and six full rehabilitations with quadruple
zygomatic implants; after a minimum follow-up of 6 years, there was a mean bone loss
for regular implants of 1.39 ± 0.10 mm and a mean bone loss for regular implants of
1.36 ± 0.09 mm with no significant differences between the two groups [33].

Davò et al. reported in a patient with a quad zygomatic for fixed maxillary rehabilita-
tion the failure of a total of three zygomatic implants after 3 weeks [46]. In this particular
case, the subject changed the rehabilitation planning into a removable overdenture [46].
Coppedè et al. reported after a 3-year clinical prospective follow-up 1.34 ± 0.23 mm
mean bone loss for zygomatic implants and 1.10 ± 0.58 mm mean bone loss for regular
implants [45]. Probably, more long-term evaluations and histological studies should be
considered for future research to highlight the comparative responses of the peri-implant
tissues around zygomatic and conventional implants after functional loading.

Limitations of the Study

The length, diameter and macro- and microgeometry of the fixtures are determinant
for the successful osteointegration of zygomatic and regular implants [28,78,79]. No limits
regarding size, surface treatments, implant geometry, surgical approaches, techniques and
eventual regenerative procedures were imposed for the article screening. Moreover, the differences regarding prosthesis design, the research and the follow-up model could have a strong influence on the study’s effectiveness. Another important limitation of the study is that no randomized and blinded studies were included in the present investigation, which could represent a determinant bias for the statistical considerations.

5. Conclusions

In conclusion, zygomatic implants are a long term predictable option for severe maxillary atrophies treatment with combined zygomatic fixed implant-supported rehabilitation, showing a higher cumulative survival rate compared to conventional implants. More future clinical trials and histological studies on retrieved biopsies are required to evaluate the long term effectiveness of peri-implant soft and hard tissue response around zygomatic and conventional implants after loading.

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