Int. J. Morphol.,
41(1):35-44, 2023.

The Use of Zygomatic Implants in Severe Maxillary Atrophy: A Systematic and Meta-Analysis Review of Randomised Clinical Trials

El Uso de Implantes Zigomáticos para Atrofia Maxilar Severa: Una Revisión Sistemática y Meta-Análisis de Ensayos Clínicos Aleatorizados

Roberto Sacco[1,2]; Shreeya Patel[1]; Sergio Olate[3,4] & Julian Yates[1]

SACCO, R.; PATEL, S.; OLATE, S. & YATES, J. The use of zygomatic implants in severe maxillary atrophy: A systematic and meta-analysis review of randomised clinical trials. *Int. J. Morphol. 41(1)*:35-44, 2023.

SUMMARY: Conventional implant treatment cannot always be used to rehabilitate edentulous patients with advanced maxillary atrophic. Zygomatic dental implants have been used over the past 20 years as an alternative treatment solution to bone grafting. The purpose of this meta-analysis is to evaluate the implant and prosthetic survival rate in non-oncologic patients with a severely atrophic maxilla. This review also aims to better understand the rate of peri-operative complications in this cohort of patients. A multi-database (PubMed, MEDLINE, EMBASE, and CINAHAL) focused systematic search was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations. Any randomised control trials studies involving human participants treated with zygomatic osseous implants were included. After eliminating duplicates, a total of 4 studies met the inclusion criteria for this meta-analysis review. With all the studies included there was a total of 174 patients treated with zygomatic osseous implants. The overall implant success rate was 98.03 %. The prosthetic success rate was 96.4 %. The most frequent peri-operative complication was sinusitis. Based on the limited data available in literature, zygomatic dental implants represent a valid alternative to bone augmenting procedure. However, they are not without risks and longer follow-ups are required to confirm the validity of the treatment in long term.

KEY WORDS: Zygomatic Implants; Maxillary Atrophy; Rehabilitation.

INTRODUCTION

Rehabilitation of extremely atrophic maxilla is a concern and constitutes a challenge for clinicians due to the lack of bone anchorage, which ultimately influences the placement and the longevity of conventional dental implants. Studies have shown a 50 % reduction of the alveolar ridge width within the first year of dental extraction, with a subsequent annual resorption rate of 0.5-1 % (Schropp *et al*., 2003). The extent and rate of resorption are dependent on the number of teeth extracted, bone density, bone levels prior to extraction and presence of infection. Elderly patients are more likely to be edentulous and the recipients of complete dentures. They have a higher predisposition to endocrine imbalances, reduced protein metabolism, reduced resistance to stress and alimentary failure which may result in nutritional, vitamin and mineral deficiencies. These are all factors that influence normal tissue repair and regeneration and the metabolism of bone, and may accentuate resorption (Ortman, 1962). Additional factors highlighted by some clinical studies also suggest that denture wearing habits may have a significant influence on residual ridge resorption when compared to disuse atrophy alone (Carlsson *et al*., 2004; Alsaggaf *et al*., 2020). The cause of this is likely due to the pressure exerted by the denture base through the vascular tissues, which alters blood supply, increasing capillary pressure and causing inflammation of the mucoperiosteum (Ortman, 1962). Alongside this, the pneumatisation of the maxillary sinuses can further contribute to significant reduction in bone volume (Malevez *et al*., 2003).

[1] The University of Manchester Division of Dentistry, School of Medical Sciences, Oral Surgery Department, Manchester, UK.
[2] King's College Hospital, Oral Surgery Department, London, UK.
[3] Division of Oral, Facial and Maxillofacial Surgery, Universidad de La Frontera, Temuco, Chile.
[4] Center of Excelence in Morfological and Surgical Research (CEMyQ), Universidad de La Frontera, Temuco, Chile.

Received: 2022-09-25 Accepted:2022-11-17

Ultimately this can lead to a severely atrophic maxilla in both the horizontal and vertical dimensions and thus presenting considerable restorative difficulties such as inadequate retention of dentures with anatomical limitations as well as reduced quantity and quality of bone for conventional implant placement. Complicating matters further, the pattern of resorption in the maxilla is centripetal, resulting in a pseudo-class 3 prognathism (Malavez *et al*., Pietrokovski *et al*., 2007). Therefore, the combination of the amount and pattern of resorption results in difficulty with insertion of conventional implants for a successful, functional and an aesthetically pleasing result (Pietrokovski *et al*., 2007).

To overcome this, the following techniques have been employed: bone augmentation, guided bone regeneration, alveolar distraction osteogenesis, elevation of the sinus floor with or without bone augmentation, alternative implant techniques, tilted implant placement and short implants. Although autogenous onlay bone grafts are considered the gold standard in augmentation of the atrophic maxillae, the literature has shown the overall survival rate in the reconstructed maxilla and mandible to be 73.8-100 %, compared to 87 % for native bone over 10 years (Ali *et al*., 2014; Tran *et al*., 2016; Motamedian *et al*., 2016). Moreover, these complex and lengthy techniques require multiple stages, incur additional cost to the patient and practitioner, increased morbidity as a donor graft site is often required, increased time for the graft to integrate and even if successful has a reported 25 % reduction of graft height within the first year (Verhoeven *et al*., 2000; Ribeiro-Junior *et al*., 2009).

Short implants (<6mm) have proven to be a viable option to allow for simplicity and avoids the use of grafts to minimise its associated complications. However, evidence has shown that the survival rates have high variability and low predictability compared to conventional implants ranging from 86.7-100 % with shorter implants and 95-100 % for conventional (Papaspyridakos *et al*., 2018). There is also limited evidence regarding long term survival in the atrophic maxilla (Ali *et al*.).

In 1998, Branemark developed zygomatic implants for the rehabilitation of patients with maxillectomies for the treatment of tumours or systemic conditions associated with significant atrophy of the maxilla without the use of grafts (Galán Gil *et al*., 2007). This technique was adapted to facilitate provision of zygomatic implant supported prosthesis in the severely atrophic maxilla in edentulous patients. Additional benefits included successful immediate loading and functionality resulting in reduced cost and time for patients to function, decreased number of invasive surgical procedures and improved patient adaptability and acceptance. The original technique involved the use of 1-2 implants per side that were >30mm in length, which are inserted into the body of the malar prominence after lifting the sinus membrane (Stella & Warner, 2000). This technique has since been modified by Aparicio *et al*. (2008) who developed the sinus slot technique (Aparicio *et al*., 2008; Rodríguez-Chessa *et al*., 2014). Other modifications include the extra-sinus techniques for those with pronounced concavities on the lateral aspect of the maxillary sinus. This can minimise the risk of common complications associated with the procedure, such as sinus perforation and sinusitis, and allow for emergence of the implants and prosthesis at the alveolar crest rather than the palate. This in turn allows for reduced bulkiness of the final prosthesis, increased patient comfort, the ability to perform improved oral hygiene and limited impairment of speech (Aparicio *et al*., 2014; Romeed *et al*., 2015). May need to mention the extended sinus window technique for quad zygomatic implants.

Survival rates of zygomatic implants used in the severely atrophic maxilla have been reported to be between 95.2-100 % which is also the case in long term follow ups (>10 years) (Chrcanovic *et al*., 2016; Ramezanzade *et al*., 2021). However due to the technique sensitivity of this method of rehabilitation, and proximity to vital structures such as the infraorbital nerve, placement of these is recommended to be performed by suitably trained clinicians. The added benefits of zygomatic implants alongside comparable success rates when compared to conventional implants make them a suitable contender as an alternative strategy.

The aim of this meta-analysis is to assess the prosthetic and implant success rates for zygomatic implant retained prosthesis in the atrophic maxilla. A subgroup analysis also looked at the effectiveness of piezoelectric surgery compared with conventional drills for this procedure and the use of an intranasal antrostomy to reduce the incidence of sinusitis – a common complication associated with intra-sinus zygomatic implant placement.

MATERIAL AND METHOD

This systematic review was performed according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Liberati *et al*., 2009).

The following four databases were explored: PubMed, MEDLINE, EMBASE and CINAHL. A three-stage

focused screening approach was used to guarantee quality assurance of the searches. The screening of titles and abstracts was carried out independently by two authors (RS, SP) to eliminate irrelevant material (i.e., reviews, animal studies, non-clinical studies and non-randomised control studies). Disagreements were resolved by discussion with a third and fourth author (JY, SO) until a consensus was reached.

A data screening and abstraction form was used to:

- Verify the study eligibility derived from the inclusion/ exclusion criteria.
- Carry out the methodological quality assessment.
- Extract data on study characteristics and outcomes for the included studies (Fig. 1).

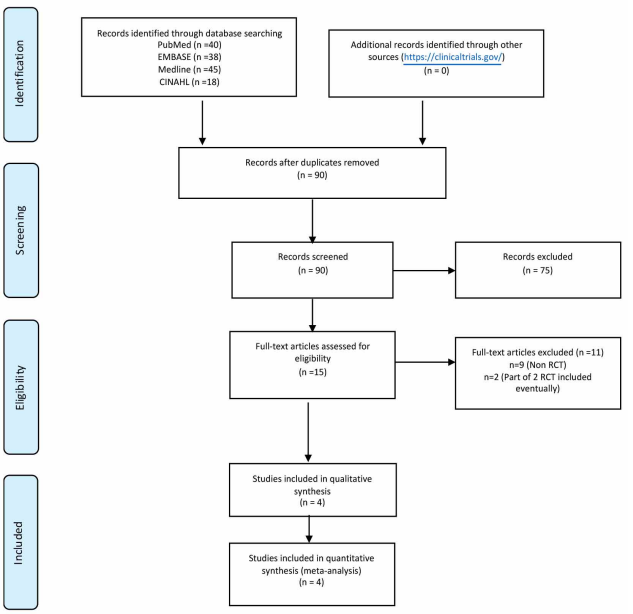

Fig. 1. Prisma study flow diagram.

The authors of any studies eligible for inclusion in the review with insufficient information were contacted directly. Clinical questions were broken down and formulated using the PICOS framework (Schardt *et al*., 2007).

Focused question and PICO strategy. Is there any evidence that zygomatic dental implants in atrophic maxilla are more successful with minimal operative complications comparing with any conventional treatments (e.g all-on-four and/or bone grafting procedures).

- Population (P): any adult patients (>18 years-old) with atrophic maxilla.
- Interventions (I): any type of zygomatic dental implant placement.
- Comparison (C): with any augmented procedure (sinus lift), conventional implant placement (all-on-four) and type of zygomatic dental implant placement (QUOD, piezoelectric placement)
- Outcome (O): state of knowledge regarding implant and prosthetic success rate.
- Study (S): only randomised control trials

Criteria for Inclusion in this Review

Types of Studies. The types of studies included in the research strategy were published or unpublished randomised controlled trials. Papers were obtained from January 1980 to June 2022. No language restrictions were imposed on the search.

Types of Participants. The review considered studies involving any patient who needed zygomatic dental implants due to severely atrophic maxilla. There was no restriction on the minimum number of patients included in the studies.

Outcomes measured

- **Primary outcomes**
  - Zygomatic dental implant success rate.
  - Zygomatic prosthetic rehabilitation success rate.
- **Secondary outcomes**
  - Peri-operative complication

Data Extracted. All selected papers were carefully read to identify author(s); year of publication; study design; population and treatment characteristics.

Data extracted from the studies included the number of patients; patient gender and age; type of zygomatic dental implant placement; type of complications and success rate of implant and prosthetic rehabilitation.

In the case of missing data, authors were contacted allowed six weeks for a reply. If the information was still missing, missing data was recognised as 'Not Reported (NR)' in the results and tables.

Statistical analysis. Data were analysed using JAMOVI (The Jamovi Project, 2021). Results were expressed as mean and standard deviation (SD) for quantitative variables and as numbers and proportions for categorical findings. A proportional meta-analysis was applied for all the studies. The survival and complication of the included studies were evaluated by proportional rate (effect size) and corresponding 95 % confidence interval (CI).

The meta-analysis was performed using the random effects model. Heterogeneity of the studies was assessed by calculating the Q-statistic and the associated I^2 coefficient. The Z-test was used to compare the proportions between groups. Meta-analyses of each of the sub-groups were represented with a forest plot and a funnel plot.

Review Quality Assessment Data. Two review authors (RS, SP) appraised the risk of bias in the included study with the tool recommended by the Cochrane Handbook for Systematic Reviews of Interventions as appropriate for randomised control trials (RCTs). Any disagreements in risk of bias assessments were referred to another author of the review team (JY) and subsequently resolved by discussion.

RESULTS

The four final studies selected were randomised controlled trials published in English (Fernández Olarte *et al*. 2015; Felice *et al*., 2020; Pistilli *et al*., 2020; Fernández-Ruiz *et al*., 2021). One study was a split mouth randomised controlled trial and the remaining were 2-arm parallel design randomised controlled trials. The follow up period ranged from 3 months to 3 years. The main characteristics of the studies included are described in Tables I and II according to number of patients, number of zygomatic and regular implants, implant and prosthetic success rates, type of implant loading, complication rate and follow-up period.

Overall, there were 139 patients receiving 497 zygomatic implants and 76 patients receiving 495 conventional implants. All studies reported an overall survival rate of 98.03 % for zygomatic implants within 3 months to 3 years. These figures are 98.69 % at 4 months and 98.47 % at 1-year post loading for zygomatic implants. In terms of conventional implants including all-on-four, 2 studies reported an overall survival rate of 91.52 % between 3 months to 36 months. This figure was 92.93 % at 4 months and 1-year post loading. For conventional implants with bone augmentation alone, this figure was 82.4 % after a 3-year review. For all-on-four implants, the survival rate was 100 % after a 19-month review.

The prosthetic survival rate was greater for zygomatic implant retained prosthesis. The 3 studies that included data on prosthetic survival rate showed an overall survival rate of 96.4 % for zygomatic implant retained prosthesis from 19.4 months to 3 years. The highest prosthetic survival rate for zygomatic implant retained prosthesis was reported to be 100 % in one study and the lowest was 90 % over 3-year follow-up. The prosthetic survival rate for conventional implant retained prosthesis was 80 % over 3 years and the all-on-4 implant retained prosthesis was 92.5 % over 20.25 months.

The overall complication rate for zygomatic implants was 20.6 % - the highest reported by one study was 39 % and lowest was 5 %. The overall complication rate for conventional implants was 12.6 % and for all-on-four this was 0 %. However, 12.5 % of the all-on-four prosthesis had excessive accumulation of food beneath the definitive prosthesis. Furthermore, 11.87 % also presented with peri-implantitis. The most frequent complication noted for zygomatic implants was maxillary sinusitis with an overall occurrence rate of 5.18 %. Another frequent complication noted was sinus perforation, peri-implant mucositis and pain and swelling associated with mobile implants. One of the studies showed an overall statistically significant reduction in complications for zygomatic implants placed in addition with an intranasal antrostomy. This was an important finding as it improves patient comfort and acceptance of zygomatic implant placement. Another study compared the outcomes of zygomatic implants when inserted with a conventional drill vs piezoelectric. They reported similar clinical outcomes but found conventional drills took an average of 14.35 +/- 1.76 min longer and had an increased occurrence of post-operative haematomas.

All the trials were carried out in multicentre settings including hospital and private dental clinics.

The patients were initially provided with an immediate screw retained metal reinforced acrylic or resin fixed provisional prosthesis after which the definitive prostheses were fitted between 4 months to 1 year. All zygomatic implants were immediately loaded within 2 to 7 days and the conventional between 6 and 12 months.

Table I. Articles included for the qualitive analysis.

Authors	Number of Patients	Zygomatic Implants (n°)	Regular Implants (n°)	Type of implant loading
Fernández Olarte *et al.* 2015	44 (G1=22; G2=22)	137	0	Not specified
Fernández-Ruiz *et al.* 2021	80 (G1=40; G2=40)	139	257	Immediate
Felice *et al.* 2020	71 (G1=35; G2=36)	141	238	Immediate vs conventional
Pistilli *et al*. 2020	20 (Split-mouth)	80	0	Immediate

Table II. Summary of the RCT included in the review according to patients treated, zygomatic and regular implants placed and implant loading protocol.

Authors	Zygomatic configuration (eg. Single, quad, triple)	Type of Prosthesis	Failed Zygomatic Dental Implants	Zygomatic Implant Survival Rate	Prosthetic Success rate	Complications (%) (rate and type)	Follow -Up (days)
Fernández Olarte *et al.* 2015	Not specified	Not specified	1	99.27 %	Unspecified	Rate: 15.9 % Type: x3 sinusitis x2 subcutaneous malar emphysema x1 infraorbital paraesthesia x1 implant loss	91 days
Fernández-Ruiz *et al*. 2021	2-4 Zygomatic implants	Screw retained Immediate fixed resin prosthesis followed by screw retained definitive metal-resin fixed prosthesis	0	100 %	100 %	Rate: 5 % Type: x1 sinusitis x1 orbital cellulitis	590 days
Felice *et al.* 2020	Quad- zygomatic implants - x2 per side or x1 zygomatic per side	Screw retained metal reinforced acrylic cross arch provisional prosthesis Followed by definitive screw retained cross arch fixed procera implant bridge titanium with ceramic or acrylic materials	6	95.7 %	94.3 %	Rate: 39 % Type: x4 Sinus perforation x2 major swelling x3 mobile and painful implants x4 sinusitis x1 zygoma + periorbital infection x2 headache x1 Maxillary tumefaction x1 peri-implant mucosa recession at front implants x1 Peri-implant mucositis x1 vestibular exposure implant thread x1 fracture of resin prosthetic lining x1 fracture of MUA abutment screw of left anterior standard implant	1096 days
Pistilli *et al* 2020 [28]	x2 Zygomatic per side	Immediate screw retained metal reinforced acrylic provisional prosthesis	2	97.5 %	90 %	Rate: 22.5 % Type: Drill: x2 burn marks on inferior lip, x1 fracture at zygoma during implant placement, x1 pain/swelling/implant mobility and x2 peri-implant mucositis Piezoelectric: x1 pain/swelling/mobility of implants, x1 implant fenestration, x1 protrusion of implant, felt extra orally	1096

Meta-Analysis Evaluation. For the metadata evaluation, all papers included were considered with a minimum of 3 months follow-up with a zygomatic and regular implant-combined fixed rehabilitation. The minimum follow-up period of the selected studies was 3 months, and the maximum 36 months. The incidence of zygomatic dental implants failure was included in the meta-analysis and combined using a random effects model with the Mantel–Haenszel method. The analysis showed a significant overall effect [p = 0.077; Z = 1.77]; heterogeneity [p = 0.119; df: 3.000; I2: 54.37 %]. The odds ratio (OR) was 0.01 (95 CI: -0.001 – 0.027) (Figs. 2 and 3).

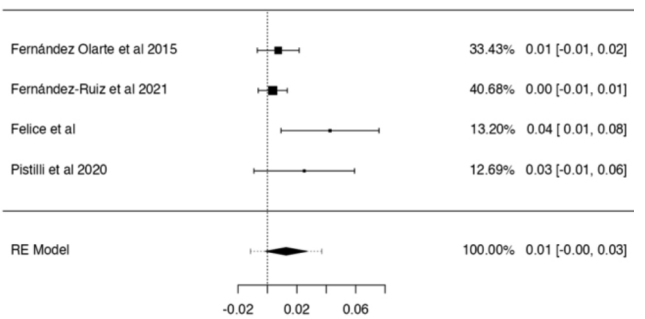

Fig. 2. Forest plot of the zygomatic implant failure.

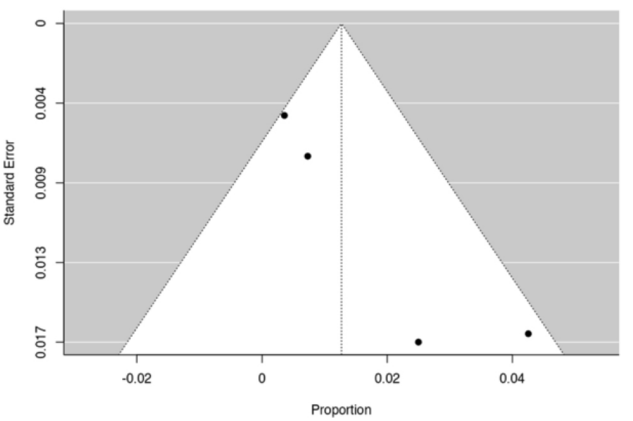

Fig. 3. Funnel plot of the zygomatic implant failure.

The incidence of complications in patients with zygomatic implants in all 4 studies were combined using a random effects model. The meta-analysis detected high heterogeneity between the combined studies (Q-test = 121.072; p = < 0.001; I2 = 97.31 %) (Figs. 4 and 5).

Risk of bias in included studies

The risk of bias of the included studies are represented in Figure 6.

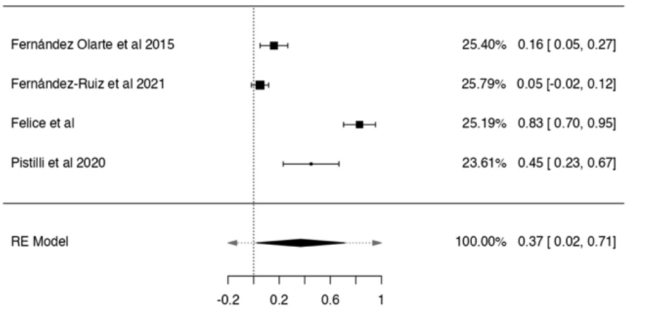

Fig. 4. Forest plot of the complications associated with zygomatic implant placement.

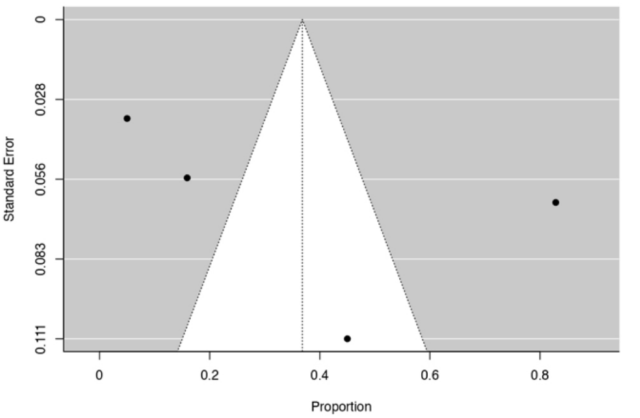

Fig. 5. Funnel plot of the complications associated with zygomatic implant placement.

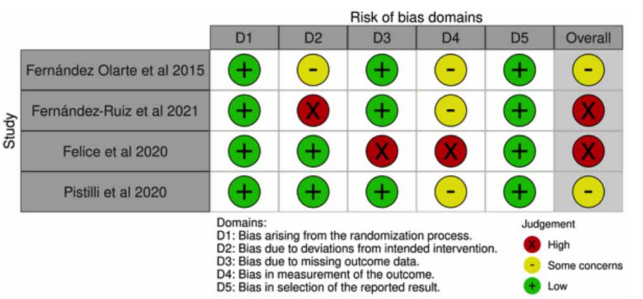

Fig. 6. Summary of Risk of bias assessment for the studies included

Randomisation - The method of sequence generation was noted in all the studies and participants were assigned by using either a computer randomization program or online randomization service. Hence, the level of the risk of bias was considered low for all the studies included in this review.

Intervention and blinding bias - Risk of bias due to deviations from the intended interventions was considered low for Felice *et al*. (2020) and Pistilli *et al*. (2020) and the blinding of patients and assessors were methodically followed. Some concerns were identified with the studies

conducted by Fernández Olarte *et al*. (2015) and Fernández-Ruiz *et al*. (2021). They had a high risk of bias due to no explanation regarding the blinding process.

Missing data bias - Risk of bias due to missing outcome data was considered low for Fernández Olarte *et al*. (2015), Fernández-Ruiz *et al*. (2021). and Pistilli *et al*. (2020). This was due to adequate study population for an analysis of the intention to treat effect. Contrastingly, Felice *et al*. (2020) was considered to have high risk of bias due to high number of dropouts.

Outcome bias - Risk of bias in measurement of the outcome was considered in Fernández Olarte *et al*. (2015), Fernández-Ruiz *et al*. (2021). and Pistilli *et al*. (2020) with some concerns due to the variables associated with the use of 4 zygoma dental implants in some subjects in the study groups. Felice *et al*. (2020) was considered to have high risk of bias due to high number of dropouts.

Reporting bias - Risk of bias in selection of the reported result was low in all the studies included in the research.

Overall bias ad quality - The overall quality of the studies included in this review were considered poor, especially those by Fernández-Ruiz *et al*. (2021) and Felice *et al*. (2020) while Fernández Olarte *et al*. (2015) and Pistilli *et al*. (2020) were considered as studies with some concerns. A summary of the risk of bias is illustrated in Figure 6.

DISCUSSION

Overall, zygomatic implant retained prosthesis in the severely atrophic maxilla shows promising results and this is in alignment with other non-RCT studies published. The evidence appears to be sufficiently robust thus far from the literature and the results of the meta-analysis are favourable. However, an insufficient number of patients have been evaluated for a limited duration in this meta-analysis. As a result, there is no strong conclusion for the clinical outcomes for implant and prosthesis success, augmentation failures and quality of life scores for long term comparison between zygomatic implants and other implant treatment for the atrophic maxilla. Despite the smaller sample size and the primary limitation being the shorter review period in the meta-analysis, much of the literature has demonstrated high cumulative success rates (CSR) for zygomatic implants over long periods. For example, Chrcanovic *et al*. (2016) reported a 12-year CSR of 95.21 %. Similarly, Bedrossian *et al*. (2010) found a 97.3 % success rate over 7 years which therefore exhibits predictable outcomes.

The results of the meta-analysis demonstrated that rehabilitation with zygomatic implants had higher prosthetic success rates when compared with conventional implants and these findings were statistically significant. However, in the study by Davó *et al*. (2018), 38 patients did not receive the definitive prosthesis for the first 4 months in function and 9 received an alternative definitive prosthesis. There was also no further information as to whether these participants were equally distributed between the conventional and zygomatic implant groups. Therefore, it cannot be determined whether this impacted prosthesis failure rate for the augmented vs zygomatic groups (Davó *et al*., 2018). In the study by Esposito *et al*. (2018) none of the participants received the definitive prosthesis during the first year in function. The fact that definitive prosthesis delivery was delayed in both studies makes it difficult to assess the true long-term success of the definitive prosthesis in function (Esposito *et al*., 2018).

Three of the 8 prosthetic failures in the augmented group in the paper by Felice *et al*., (2020) were because of the implants becoming mobile at the abutment connection. Factors contributing to this reported in the literature include poor prosthesis fit, micromovement, poorly machined components and excessive loading generating potential stress at the interface (Jain *et al*., 2018). The literature has demonstrated screw loosening to be an unusual complication for metal ceramic implant supported prosthesis with a failure rate of only 4.7 % (Sailer *et al*., 2022). Therefore, this could insinuate that the metal-reinforced acrylic prosthesis in the study may have had an unsatisfactory fit contributing to the complication of screw loosening. In the study by Fernandez-Ruiz, 7.5 % of the all-on-four prosthesis fractured their provisional prosthesis and a further 15.5 % had excessive accumulation of food and debris beneath the prosthesis (Fernández-Ruiz *et al*., 2021). There were no prosthetic complications in those with zygomatic implants. Excessive accumulation of food may be as a result from sub-optimal design of the prosthesis or improper maintenance, but fractures according to the literature, may be because of an uncontrolled occlusion and overloading of the prostheses (Soto-Penaloza *et al*., 2017). This may insinuate that zygomatic implant retained prosthesis are better adapted.

Another interesting point to note is cluster implant failures. None of the studies included in the meta-analyses included exclusion of patients with parafunctional habits. Despite no causal relationship between this and implant failure, this is an important factor to consider due to mechanical complications that can arise with placement of excessive force onto the implants causing biomechanical overload (Hanif *et al*., 2017). A case report in the literature suggested the use of zygomatic implants to overcome clus-

ter failure due to the increased cortical bone support and distribution, thus providing improved primary stability. As this variable was not controlled, the results may have been skewed in the zygomatic implant supported prosthesis favour.

Nonetheless, there are numerous benefits associated with zygomatic implant supported prosthesis such as immediate loading in function and fewer prosthesis failures. However, long term standardised data is required for a firmer conclusion.

A study regarding the perception of conventional implant retained prosthesis conducted in 2015 found that 41.2 % of patients felt that the long treatment time was a major disadvantage (Kohli *et al*., 2015). Zygomatic implants can be loaded and used immediately with a mean of 5.3 days for the implants to be loaded as shown by the meta-analysis. This overcomes an important negative viewpoint that patients have towards implant procedures. The Oral Health Impact Profile (OHIP) reported by 2 studies in the meta-analysis showed that zygomatic implants have significantly improved OHIP scores post placement. Treatment modalities are usually patient led and this result means patients and practitioners may become more accepting and allow for a slow transition of zygomatic implants to become the new gold standard for the atrophic maxillae (Felice *et al*., 2020; Fernández-Ruiz *et al*., 2021).

Zygomatic implant placement can be associated with increased complications due to their proximity to adjacent intricate vital structures increasing the risk of adverse surgical outcomes, most notably sinusitis. This is supported by the results of the studies in the meta-analysis and literature. One review in the literature determined the complication rate for sinusitis to be 7.5 % over the follow up period of 6-48 months, but this figure has been reported to be up to 26.6 % (Becktor *et al*., 2005; Fernández *et al*., 2014; Nocini *et al*., 2022). Furthermore, one study showed 9.7 % of implants had to be removed due to recurrent sinusitis over the follow up period of 9-69 months. Branemark in 2004 followed up 28 patients for at least 5 years and reported 14.3 % of patients developing recurrent sinusitis that recovered with an inferior meatal antrostomy (Brånemark *et al*., 2004). This demonstrates that sinusitis can be a persistent complication and develop months to years post-operatively. One limitation in the study conducted by Fernández Olarte *et al*. (2015) was the reduced follow up period of only 3 months as this did not take into consideration the possibility of recurrent sinusitis beyond that timeframe. Management for this can include extra-sinus implant placement or an intranasal antrostomy which have shown to reduce the incidence.

The study by Felice *et al*. (2020) reported an increased incidence of post-operative paraesthesia of the infraorbital nerves. Although brief, this unpleasant complication is likely to be a concern for patients as damage to the nerve may not just result in paraesthesia but may also be accompanied by pain in the lower eyelid, ala of the nose and upper lip (Lee *et al*., 2020). Appropriate surgical planning and surgical expertise can minimise this risk. The paper highlighted that this complication occurred more frequently in one group than the other due to differing surgical approaches and experience. The emerging evidence within the literature and this meta-analysis may eventually increase the uptake of zygomatic implants as treatment provision in the atrophic maxillae in which case further training should be made available for practitioners to provide this treatment safely and confidently. Furthermore, they will need the skills to manage the complications. The protocol for placement and success over alternative treatment modalities is well documented and is likely to become the gold standard in the future with emerging evidence (Ramezanzade *et al*. 2021). Overall, the majority of the complications reported in the meta-analysis and literature are reported to be manageable and transient with a good prognosis (Ramezanzade *et al*., 2021).

The included papers had relatively wide-ranging heterogeneity in terms of study design, lack of standardisation of the procedures due to different clinicians and multiple locations for the provision of treatment, the choice of a one stage or two stage sinus-lift procedure and different implant sizes/diameters potentially affecting outcomes.

Furthermore, cortical bone anchorage and type of bone available will inevitably impact the zygomatic implant biomechanics (Gümrükçü *et al*., 2019). The differences in size of implants could also play a key role as bone support at 10mm has double the stress of 15mm and 20mm, and in the study by Felice *et al*. (2020) there were varying sizes used which could have impacted success rate (Romeed *et al*., 2014). Despite these impacts, zygomatic implants clearly showed high success rates for the implants and prosthesis.

One of the randomised controlled trials (RCTs) have planned post loading follow-up between 5-15 years and therefore would provide more robust and consistent evidence and a more accurate accumulative success rate when evaluated at the end of the study.

The strengths of this meta-analysis include the fact that only randomised controlled trials were included and therefore used prospective data.

CONCLUSION

Overall, it appears as though the benefits provided by zygomatic implants in terms of improved quality of life, longevity, success, and appear to overshadow the mild and manageable complications that arise post-placement. The results of the meta-analysis are in favour of the use of zygomatic implant retained prosthesis over other methods, but long-term data is required to corroborate the conclusions.

SACCO, R.; PATEL, S.; OLATE, S. & YATES, J. Uso de implantes zigomáticos para atrofia maxilar severa: Una revisión sistemática y metanálisis de ensayos clínicos aleatorizados. *Int. J. Morphol. 41(1)*:35-44, 2023.

RESUMEN: Los tratamientos convencionales con implantes no siempre pueden ser usados para rehabilitar pacientes edentulos con atrofia maxilar avanzada. Los implantes dentales zigomáticos son usados por los pasados 20 años como alternativa de tratamiento a las reconstrucciones óseas. El objetivo de este meta-análisis es evaluar la sobrevida de implantes y prótesis en pacientes no oncológicos con maxila severamente atrófica. Esta revisión también pretende entender al promedio de complicaciones peri operatorias en esta cohorte de pacientes. Una búsqueda sistemática en bases de datos múltiples (PubMed, MEDLINE, EMBASE y CINAHAL) fue desarrollada de acuerdo a recomendaciones de Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Cualquier estudio clínico aleatorizado de participantes humanos donde se utilizaron los implantes zigomáticos fueron incluidos. Después de eliminar duplicados, un total de 4 estudios cumplieron los criterios de inclusión para esta meta análisis. Con todos los estudios incluidos se obtuvieron 174 pacientes tratados con implantes zigomáticos. El promedio de éxito fue de 98,03 %. El promedio de éxito de la rehabilitación fue de 96,4 %. La complicación mas frecuente fue la sinusitis. Basados en los datos limitados en la literatura, los implantes zigomáticos representan una alternativa valida a los procedimientos de aumento óseo. Sin embargo, estos no están libres de riesgos y seguimientos de mayores periodos son necesarios para confirmar la validez de los tratamientos en el largo plazo.

PALABRAS CLAVE: Implantes Zigomáticos; Atrofia Maxilar; Rehabilitación.

REFERENCES

Ali, S. A.; Karthigeyan, S.; Deivanai, M. & Kumar, A. Implant rehabilitation for atrophic maxilla: a review. *J. Indian Prosthodont. Soc., 14(3)*:196-207, 2014.

Alsaggaf, A. & Fenlon, M. R. A case control study to investigate the effects of denture wear on residual alveolar ridge resorption in edentulous patients. *J. Dent., 98*:103373, 2020.

Aparicio, C.; Manresa, C.; Francisco, K.; Aparicio, A.; Nunes, J.; Claros, P. & Potau, J. M. Zygomatic implants placed using the zygomatic anatomy-guided approach versus the classical technique: a proposed system to report rhinosinusitis diagnosis. *Clin. Implant Dent. Relat. Res., 16(5)*:627-42, 2014.

Aparicio, C.; Ouazzani, W. & Hatano, N. The use of zygomatic implants for prosthetic rehabilitation of the severely resorbed maxilla. *Periodontol. 2000, 47*:162-71, 2008.

Becktor, J. P.; Isaksson, S.; Abrahamsson, P. & Sennerby, L. Evaluation of 31 zygomatic implants and 74 regular dental implants used in 16 patients for prosthetic reconstruction of the atrophic maxilla with cross-arch fixed bridges. *Clin. Implant Dent. Relat. Res. 7(3)*:159-65, 2005.

Bedrossian, E. Rehabilitation of the edentulous maxilla with the zygoma concept: a 7-year prospective study. *Int. J. Oral Maxillofac. Implants, 25(6)*:1213-21, 2010.

Brånemark, P. I.; Gröndahl, K.; Ohrnell, L. O.; Nilsson, P.; Petruson, B.; Svensson, B.; Engstrand, P. & Nannmark, U. Zygoma fixture in the management of advanced atrophy of the maxilla: technique and long-term results. *Scand. J. Plast. Reconstr. Surg. Hand Surg., 38(2)*:70-85, 2004.

Carlsson, G. E. Responses of jawbone to pressure. *Gerodontology, 21(2)*:65-70, 2004.

Chrcanovic, B. R.; Albrektsson, T.; Wennerberg, A. Survival and Complications of Zygomatic Implants: An Updated Systematic Review. *J. Oral Maxillofac. Surg., 74(10)*:1949-64, 2016.

Davó, R.; Felice, P.; Pistilli, R.; Barausse, C.; Marti-Pages, C.; Ferrer-Fuertes, A.; Ippolito, D. R. & Esposito, M. Immediately loaded zygomatic implants vs conventional dental implants in augmented atrophic maxillae: 1-year post-loading results from a multicentre randomised controlled trial. *Eur. J. Oral Implantol., 11(2)*:145-61, 2018

Esposito, M.; Davó, R.; Marti-Pages, C; Ferrer-Fuertes, A.; Barausse, C.; Pistilli, R.; Ippolito, D. R. & Felice, P. Immediately loaded zygomatic implants vs conventional dental implants in augmented atrophic maxillae: 4 months post-loading results from a multicentre randomised controlled trial. *Eur. J. Oral Implantol., 11(1)*:11-28, 2018.

Felice, P.; Barausse, C.; Davó, R.; Pistilli, R.; Marti-Pages, C.; Ferrer-Fuertes, A.; Ferri, A. & Esposito, M. Immediately loaded zygomatic implants versus conventional dental implants in augmented atrophic maxillae: three-year post-loading results from a multicentre randomised controlled trial. *Clin. Trials Dent., 2(3)*:5-25, 2020.

Fernández Olarte, H.; Gómez-Delgado, A.; Trujillo-Saldarriaga, S. & Castro-Núñez, J. Inferior meatal antrostomy as a prophylactic maneuver to prevent sinusitis after zygomatic implant placement using the intrasinusal technique. *Int. J. Oral Maxillofac. Implants, 30(4)*:862-7, 2015.

Fernández-Ruiz, J. A.; Sánchez-Siles, M.; Guerrero-Sánchez, Y.; Pato-Mourelo, J. & Camacho-Alonso, F. Evaluation of quality of life and satisfaction in patients with fixed prostheses on zygomatic implants compared with the all-on-four concept: a prospective randomized clinical study. *Int. J. Environ. Res. Public Health, 18(7)*:3426, 2021.

Fernández, H.; Gómez-Delgado, A.; Trujillo-Saldarriaga, S.; Varón-Cardona, D. & Castro-Núñez, J. Zygomatic implants for the management of the severely atrophied maxilla: a retrospective analysis of 244 implants. *J. Oral Maxillofac. Surg., 72(5)*:887-91, 2014.

Galán Gil, S.; Peñarrocha Diago, M.; Balaguer Martínez, J. & Marti Bowen, E. Rehabilitation of severely resorbed maxillae with zygomatic implants: an update. *Med. Oral Patol. Oral Cir. Bucal, 12(3)*:E216-20, 2007.

Gümrükçü, Z. Biomechanical evaluation of zygomatic implant use in patients with different buccal maxillary defect levels. *Int. J. Oral Maxillofac. Implants, 34(6)*:e115-e122, 2019.

Hanif, A.; Qureshi, S.; Sheikh, Z. & Rashid H. Complications in implant dentistry. *Eur. J. Dent., 11(1)*:135-40, 2017

Jain, J. K.; Sethuraman, R.; Chauhan, S.; Javiya, P.; Srivastava, S.; Patel, R. & Bhalani, B. Retention failures in cement- and screw-retained fixed restorations on dental implants in partially edentulous arches: A systematic review with meta-analysis. *J. Indian Prosthodont. Soc. 18(3)*:201-11, 2018.

Kohli, S.; Bhatia, S.; Kaur, A. & Rathakrishnan, T. Patients awareness and attitude towards dental implants. *Indian J. Dent. 6(4)*:167-71, 2015.

Lee, S. Y.; Kim, S. H.; Hwang, J. H. & Kim, K. S. Sensory recovery after infraorbital nerve avulsion injury. *Arch. Craniofac. Surg., 21(4)*:244-8, 2020.

Liberati, A.; Altman, D. G.; Tetzlaff, J.; Mulrow, C.; Gøtzsche, P. C.; Ioannidis, J. P.; Clarke, M.; Devereaux, P. J.; Kleijnen, J. & Moher, D. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *J. Clin. Epidemiol., 62(10)*:e1-34, 2009.

Malevez, C.; Daelemans, P.; Adriaenssens, P. & Durdu, F. Use of zygomatic implants to deal with resorbed posterior maxillae. *Periodontol. 2000, 33*:82-9, 2003.

Motamedian, S. R.; Khojaste, M. & Khojasteh, A. Success rate of implants placed in autogenous bone blocks versus allogenic bone blocks: A systematic literature review. *Ann. Maxillofac. Surg., 6(1)*:78-90, 2016.

Nocini, R.; Panozzo, G.; Trotolo, A. & Sacchetto, L. Maxillary sinusitis as a complication of zygomatic implants placement: a narrative review. *Appl. Sci., 12*:789, 2022.

Ortman, H. Factors of bone resorption of the residual ridge. *J. Prosthet. Dent., 12(3)*:429-40, 1962.

Papaspyridakos, P.; De Souza, A.; Vazouras, K.; Gholami, H.; Pagni, S. & Weber, H. P. Survival rates of short dental implants (≤6 mm) compared with implants longer than 6 mmin posterior jaw areas: A meta-analysis. *Clin. Oral Implants Res., 29 Suppl. 16*:8-20, 2018.

Pietrokovski, J.; Starinsky, R.; Arensburg, B. & Kaffe, I. Morphologic characteristics of bony edentulous jaws. *J. Prosthodont., 16(2)*:141-7, 2007.

Pistilli, R.; Esposito, M.; Barausse, C.; Balercia, A.; Bonifazi, L.; Buti, J. & Felice, P. Conventional drills versus piezoelectric surgery preparation for placement of four immediately loaded zygomatic oncology implants in edentulous maxillae: 3-year results of a within-person randomised controlled trial. *Clin. Trials Dent., 2(2)*:5-17, 2020.

Ramezanzade, S.; Yates, J.; Tuminelli, F.J.; Keyhan, S.O.; Yousefi, P.; Lopez-Lopez, J. Zygomatic implants placed in atrophic maxilla: an overview of current systematic reviews and meta-analysis. *Maxillofac. Plast. Reconstr. Surg., 43(1)*:1, 2021.

Ribeiro-Junior, P. D.; Padovan, L. E.; Gonçales, E. S. & Nary-Filho, H. Bone grafting and insertion of dental implants followed by Le Fort advancement for correction of severely atrophic maxilla in young patients. *Int. J. Oral Maxillofac. Surg., 38(10)*:1101-6, 2009.

Rodríguez-Chessa, J. G.; Olate, S.; Netto, H. D.; Shibli, J.; de Moraes, M. & Mazzonetto, R. Treatment of atrophic maxilla with zygomatic implants in 29 consecutives patients. *Int. J. Clin. Exp. Med., 7(2)*:426-30, 2014.

Romeed, S. A.; Hays, R. N.; Malik, R.; Dunne, S. M. Extrasinus zygomatic implant placement in the rehabilitation of the atrophic maxilla: three-dimensional finite element stress analysis. *J. Oral Implantol., 41(2)*:e1-6, 2015.

Romeed, S. A.; Malik, R. & Dunne, S. M. Zygomatic implants: the impact of zygoma bone support on biomechanics. *J. Oral Implantol., 40(3)*:231-7, 2014.

Sailer, I.; Karasan, D.; Todorovic, A.; Ligoutsikou, M. & Pjetursson, B. E. Prosthetic failures in dental implant therapy. *Periodontol. 2000, 88(1)*:130-44, 2022.

Schardt, C.; Adams, M. B.; Owens, T.; Keitz, S. & Fontelo, P. Utilization of the PICO framework to improve searching PubMed for clinical questions. *BMC Med. Inform Decis. Mak., 7*:16, 2007.

Schropp, L.; Wenzel, A.; Kostopoulos, L. & Karring, T. Bone healing and soft tissue contour changes following single-tooth extraction: a clinical and radiographic 12-month prospective study. *Int. J. Periodontics Restorative Dent., 23(4)*:313-23, 2003.

Soto-Penaloza, D.; Zaragozí-Alonso, R.; Penarrocha-Diago, M.; Penarrocha-Diago, M. The all-on-four treatment concept: Systematic review. *J. Clin. Exp. Dent., 9(3)*:e474-88, 2017.

Stella, J. P. & Warner, M. R. Sinus slot technique for simplification and improved orientation of zygomaticus dental implants: a technical note. *Int. J. Oral Maxillofac. Implants, 15(6)*:889-93, 2000.

The Jamovi Project. *Computer Software (Version 1.6)*. Jamovi, 2021. Available from: https://www.jamovi.org

Tran, D. T.; Gay, I. C.; Diaz-Rodriguez, J.; Parthasarathy, K.; Weltman, R. & Friedman, L. Survival of Dental Implants Placed in Grafted and Nongrafted Bone: A Retrospective Study in a University Setting. *Int. J. Oral Maxillofac. Implants, 31(2)*:310-7, 2016.

Verhoeven, J. W.; Ruijter, J.; Cune, M. S.; Terlou, M. & Zoon, M. Onlay grafts in combination with endosseous implants in severe mandibular atrophy: one year results of a prospective, quantitative radiological study. *Clin. Oral Implants Res., 11(6)*:583-94, 2000.

Corresponding author:
Roberto Sacco
The University of Manchester
Division of Dentistry
School of Medical Sciences
Oral Surgery Department
Coupland 3 Building
Oxford Rd
Manchester M13 9PL
UNITED KINGDOM

E-mail: roberto.sacco@manchester.ac.uk