The journal of
PROSTHETIC AND IMPLANT DENTISTRY
Official Publication of Indian Prosthodontic Society
Kerala State Branch

REHABILITATION OF ATROPHIC MAXILLA WITH PTERYGOID IMPLANTS: A SYSTEMATIC REVIEW

*Neelam Pande, **Anushree Bhoge

*Professor and HOD, **Senior Lecturer, Department of Prosthodontics, RDDC, Nagpur |
Corresponding author: Dr. Anushree Bhoge, E-mail: bhogeanushree13@gmail.com

https://doi.org/10.55231/jpid.2024.v08.i01.01

Abstract:

Aim:-To outline the evidence on the use of pterygoid implants in the rehabilitation of atrophic maxilla.

Methods:-A comprehensive electronic search in PubMed and Google scholar was carried out to screen relevant articles based on title, abstract, and full text published in English language between January 2013 and June 2023. Studies assessing the clinical outcomes, survival rate, complication of pterygoid implants when used in atrophic maxilla were eligible for this review while studies focusing on the ideal length, angulation for implant placement, letter to editors, review articles, short communications and conference proceeding were excluded.

Results:- A preliminary search yielded a total of 28 studies through search strategy used in Pub Med and Google Scholar. After screening, six articles were included for qualitative synthesis while the remaining articles were excluded for being duplicates, virtual studies, focusing on parameters other than the predefined objectives of this review, and not providing relevant data. The survival rate in the included studies ranged from 88.06% –100%. The clinical outcomes reported were probing depth, sulcus bleeding, and plaque. The marginal bone loss ranged from 0.28–1.21 mm. Post-operative complications like mucositis, fractured prosthesis, chipping of ceramic, peri-implant mucositis, and mobility, bleeding or discomfort were observed in 1.02% (13 of 1,279) of the patients.

Conclusion:- The survival rate of pterygoid implants when used in an atrophic maxilla is high. These implants lead to a minimum marginal bone loss. Further, the complications associated with pterygoid implants are also minimal with no clinical significance.

Keywords: pterygoid implant, atrophic maxilla, rehabilitation, survival rate, complications

Introduction

An increase in advancement in the field of medicine and science, there is an increase in the lifespan observed in the population. However, along with this benefit, the old age diseases have also become prevalent.[1] According to the Global Oral Health Status report of World Health Organiza-

tion 2022, the estimated global prevalence of complete edentulism in people above 20 years was around 7% while the rate reaches 23% for people aged 60 years and above.[2]Dentures and bridges still remain the traditional way of rehabilitating loss teeth. However, the advances in treatment i.e., the use of dental implants have shown a remarkable increase in the last 30 years owing to its high success rate.[3] The10-year survival rate of dental implants is estimated to be 96.4%.[4] Moreover, the complications associated with dental implants are also reported to be low.[5]

Based on the relationship of implants with the oral tissues; the endosteal, subperiosteal, and transosseous implants are the three major categories of implants.[6] Per-Ingvar Branemark's theory of osseointegration expanded the range of restorative options for patients who were either partially or completely edentulous. Osseointegration is explained as a direct functional as well as structural connect between the surface of osseous implant and the living bone.[7] It thus allows for a new bone formation around its surface thereby forming a fusion and improving the stability and success rate of the prosthesis. For osseointegrated implants, the 4–9 years success rate was 89.06% for individual implant while 100% for prosthetic treatment.[8]

Dental implants continue to have a certain percentage of implant failures despite a steady rise in their success rate. Poor bone quality, infection that impedes primary bone healing, and a lack of primary stability due to trauma during surgery, are some of the local causes of implant failure whereas, corticosteroids, uncontrolled diabetic mellitus, collagen abnormalities, bisphosphonate medication, and osteoporosisare other systemic diseases that affect the early stages of bone regeneration. It is to be noted that, apart from these causes, the site at which the implant is placed also hold a great importance in the success of prosthesis.[9] and for the same reason;

Table 1: Search strategy used in Pub Med database

Sl. No.	Search strategy
1	("pterygoid implant"[All Fields] AND ("maxilla"[MeSH Terms] OR "maxilla"[All Fields] OR "maxillary"[All Fields] OR "maxillaries"[All Fields] OR "maxillaris"[All Fields]) AND ("atrophy"[MeSH Terms] OR "atrophy"[All Fields] OR "atrophic"[All Fields])) AND (y_10[Filter])
2	("pterygoid implant"[All Fields] AND (("maxilla"[MeSH Terms] OR "maxilla"[All Fields] OR "maxillary"[All Fields] OR "maxillaries"[All Fields] OR "maxillaris"[All Fields]) AND ("atrophie"[All Fields] OR "atrophy"[MeSH Terms] OR "atrophy"[All Fields] OR "atrophied"[All Fields] OR "atrophies"[All Fields] OR "atrophying"[All Fields])) AND ("rehabilitant"[All Fields] OR "rehabilitants"[All Fields] OR "rehabilitate"[All Fields] OR "rehabilitated"[All Fields] OR "rehabilitates"[All Fields] OR "rehabilitating"[All Fields] OR "rehabilitation"[MeSH Terms] OR "rehabilitation"[All Fields] OR "rehabilitations"[All Fields] OR "rehabilitative"[All Fields] OR "rehabilitation"[MeSH Subheading] OR "rehabilitation s"[All Fields] OR "rehabilitational"[All Fields] OR "rehabilitator"[All Fields] OR "rehabilitators"[All Fields])) AND (y_10[Filter])
3	("pterygoid implant"[All Fields] AND (("maxilla"[MeSH Terms] OR "maxilla"[All Fields] OR "maxillary"[All Fields] OR "maxillaries"[All Fields] OR "maxillaris"[All Fields]) AND ("atrophie"[All Fields] OR "atrophy"[MeSH Terms] OR "atrophy"[All Fields] OR "atrophied"[All Fields] OR "atrophies"[All Fields] OR "atrophying"[All Fields])) AND ("survival rate"[MeSH Terms] OR ("survival"[All Fields] AND "rate"[All Fields]) OR "survival rate"[All Fields])) AND (y_10[Filter])

there are still certain limitations to implant success in maxillary posterior region compared to anterior region. The posterior maxilla presents a biological and anatomical challenge due to its proximity to the maxillary sinus and its reduced residual bone volume after tooth loss combined with poor bone density.[10] This is especially true if the tooth loss happened years ago. As a result, it has long been difficult to use dental implants to reconstruct the atrophic posterior maxilla.

Due to the paucity of bone in these individuals, additional/conventional implants frequently cannot be placed without first augmenting the hard tissue. The literature has documented many augmentative procedures, with the use of xenografts, alloplastic, autologous, and allogenic materials. However, all these procedures require a healing period prior to placement of the implant and also have a high risk of complete or partial loss of graft along with significant invasiveness.[11] Zygomatic implants and all-on-4 implants were also introduced; these too presented complications of graft displacement into

Table 2:- Characteristics of the included studies

Study id	Author name	Year of publication	Study design	Sample size	Age of the patients	Implants manufacturers	Follow-up period	Evaluation method
1	Balshi TJ et al.	2013	Retrospective study	992 7-13mm: 67 15-18mm: 925	NR	Brånemark System implants (Nobel-Biocare)	[3]10 years	NR
2	Curi MM et al.	2015	Retrospective study	66	60.9 years (41 to 77 years)	Branemark System Mk III (nobelbiocare)	3 years	Panoramic radiograph
3	Ardekian L et al.	2018	Retrospective study	35	55 years (44-71 years)	Bioline Dental Implants, Frankfurt, Germany	11 months	CBCT
4	Signorini L et al.	2020	Prospective cohort study	15	Around 61 years (51-77 years)	JDPterygo; JDentalCares.r.l.	1 year	Panoramic radiograph
5	Jin W et al.	2021	Retrospective study	46	61.2 years (38-79 years)	Anodized surface, TiUnite™ technology, Nobel Biocare Active system	1 year	CBCT
6	Nag VPR et al.	2022	Retrospective study	125	NR	Angulated multiunit abutment, Bioline dental implants, Frankfurt, Germany	2 years	Panoramic radiograph and CBCT

CBCT: Cone beam computed tomography; NR: Not reported

Table 2:- Clinical outcomes and survival rate in the included studies

Author name	Success rate	Probing depth around the implants	Modified sulcus bleeding index	Plaque index	Marginal bone loss	Complications	Reason for implant failure/ complications	Inference
Balshi TJ et al.	<u>For 7- to 13-mm implants</u> 92.54% a 1 year, 2 years, 3 years, and 88.06% at ^{3}10 years <u>For 15- to 18-mm implants</u> 94.49% at 1 year, 94.38% at 2 years, 94.27% at 3 yers, and 94.16% at ^{3}10 years.	NR	NR	NR	NR	No complications observed	Lack of osseointegration	The Brånemark System 4.0-mm-diameter 15- to 18-mm implant group had a statically higher CSR than the 7- to 13-mm group in the pterygomaxillary region.
Curi MM et al.	99.0%	NR	NR	NR	1.21 mm (0.31 to 1.75)	No complications like infection, bleeding, edema, or wound dehiscence	Lack of osseointegration	Pterygoid implants in pterygoid region provide excellent stabilization for bone-anchored prosthesis in partially and completely edentulous patients.
Ardekian L et al.	91.4%	NR	NR	NR	NR	No bleeding, intraoperative or postoperative adverse events	Lack of osseointegration	Pterygoid implants have a high success rate, minor and infrequentcomplications and similar bone loss in comparison to conventionalimplants. Pterygoid implants are considered as a good alternative forextensive augmentation procedure in patients with atrophic maxilla.

Author name	Success rate	Probing depth around the implants	Modified sulcus bleeding index	Plaque index	Marginal bone loss	Complications	Reason for implant failure/ complications	Inference
Signorini L et al.	100.0%	NR	NR	NR	NR	Mucositis within four months of the surgical procedures: 3 cases Complications with the interim prosthesis: 3 cases (2 fractured, 1 chipped). No pain, or peri-implant radiolucency.	No failure	The pterygoid implants had a high success rate with minimal or no complications.
Jin W et al.	97.80%	2.30±0.54	0.13±0.40	1.16±0.76	Near: 0.64±0.46 mm Distant: 0.68±0.41 mm	Peri-implant mucositis: 2 cases No surgical complications such as haemorrhage or maxillary sinus floor perforation	Poor oral hygiene	Implant-supported full-arch fixed dentures in pterygomaxillary regions have acceptable short-term clinical outcomes and high patient satisfaction, and are a predictable and feasible restoration way.
Nag VPR et al.	96.80%				0.28 mm (0.17-0.39 mm)	Pain, prosthetic mobility, bleeding or discomfort: 4 cases (failed) Chipping of ceramic: 1 case	Lack of osseointegration	The success rates of pterygoid implants are higher and there is less bone loss around pterygoid implants when placed by TTPHIL® technique in healthy individuals.

CSR: Cumulative survival rate; TTPHIL: Tall tilted pin hole placement immediate loading

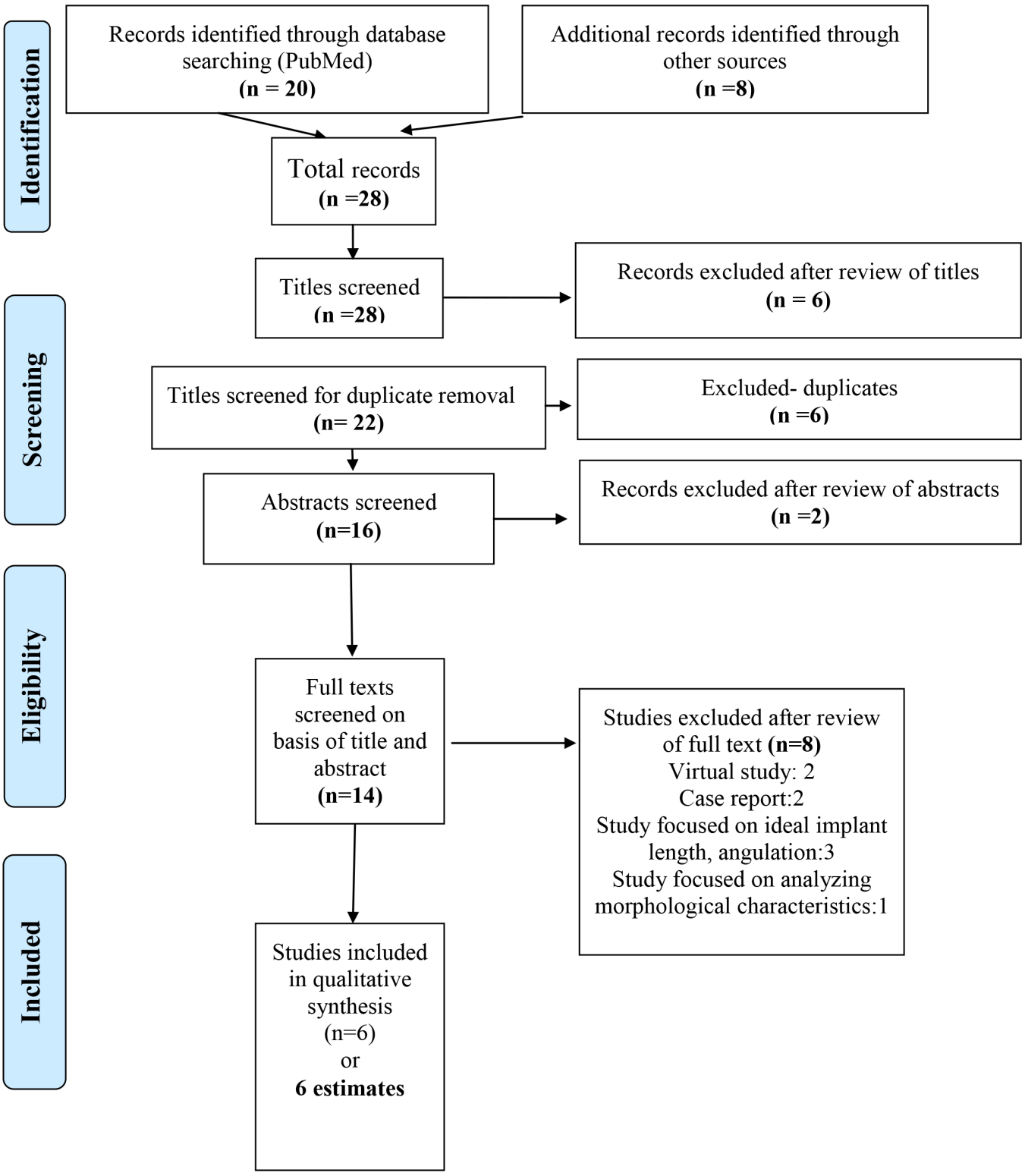

Figure 1: PRISMA Flow chart presenting screening of articles

the sinus cavity, perforation of sinus cavity, and loosening of screws of the implants.[12]In these scenarios, the researchers proposed placing implants on the posterior most part of the maxillary tuberosity and area distal to the maxillary sinus.[13] The availability of thick cortical bone for engagement of the implant is the main justification for employing pterygoid implants. Additionally, it aids in avoiding the necessity for surgeries to raise and graft the maxillary sinus. This might cut down on treatment time and enable immediate pterygoid implant loading. Further, it enables a prosthesis to have enough posterior extensions, which eliminates the necessity for cantilevers at the distal end.[14]

Nevertheless, pterygoid implant also demonstrates complications like risk of damage to the proximal structures during implant placement, technique sensitivity, difficulty in access to the posterior most regions of the maxilla, and a slow learning curve.[14] So far few systematic reviews have been conducted on pterygoid implants.[15,16] However, since last reported review, new studies have been published on pterygoid implants in atrophic maxilla providing a better knowledge. This systematic review was thus conducted with a focused question of: What are the clinical outcomes and success rate of pterygoid implants in atrophic maxilla?

Methodology

The current systematic review was conducted and written according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA Statement) checklist Recommendations and is registered with no. CRD42023435414

Literature search

Both PubMed and Google Scholar were searched in-depth for the data. The search strategy in the database was developed utilising Boolean operators, controlled vocabulary (MeSH terms in PubMed), and free-text terms and phrases in the titles and/or abstracts linked to pterygoid implants and atrophic maxilla. In Table No. 1, a thorough search method for PubMed is de-

Point of Relevance:-

1. **Survival rates:-** A high survival rate was reported in all the six included studiesof this review. The survival rate ranged from 88.06%-100% with a mean follow-up between 11 months -10 years.
2. **Clinical outcomes:-** The mean probing depth around the implant was 2.300.54 mm, sulcus bleeding as recorded by modified sulcus bleeding index was 0.130.40, and plaque recorded by plaque index was 1.160.76. These parameters were reported in only one study.
3. **Complications:-** The mean probing depth around the implant was 2.300.54mm, sulcus bleeding as recorded by modified sulcus bleeding index was 0.130.40, and plaque recorded by plaque index was 1.160.76. These parameters were reported in only one study.
4. In all the cases of failure, the major reason was lack of osseointegration.
5. The average marginal bone loss after placement of implant ranged from 0.28-1.21mm.

scribed. The best match option and the publication date were selected as the filters. In addition to looking through search results, publications were identified through exploring cross references within the selected study and browsing specialist journals for pertinent content.

Eligibility criteria

The PICO (P: patients with atrophic maxilla, I: pterygoid implants placed in maxilla, C: this review did not aim to compare the pterygoid implants with other implants thus no comparator or any comparator as implants was considered, O: survival rate, clinical outcomes, complications) based eligibility criteria included studies reporting clinical outcome and/or survival rate of pterygoid implants in pterygomaxillary region irrespective of any follow-up, number of patients, and size and diameter of the implants included. Study designs considered were prospective cohort studies, retrospective cohort studies, and randomized controlled studies published in English language between last 10 years (search conducted in June 2023) were included in the review whereas studies reporting data through animal studies, laboratory studies, cadaver studies, in-vitro studies, radiographic studies focusing on standard implant length r technique were excluded. Along with this, the reviews, editorials, conference proceedings were also excluded from this review.

Study selection

The titles and abstracts acquired through the search technique were independently reviewed by one review author (Dr. Neelam Pande), who then included them in accordance with the eligibility criteria. The entire texts of all the studies that had been included were then obtained and read in order to make a final decision on their inclusion. The second author (Dr. Anushree Bhoge) was consulted in order to clarify any uncertainties regarding study eligibility.

Data analysis

A standardized data extraction form known as a 'pilot form' was created in Microsoft Excel Spreadsheet with an expert's guidance. The form included details on the study variables like; authors, publication year, study design, sample size, patient's age, implant manufacturer, follow-up period, evaluation method, and study outcomes like; success rate, probing depth around the implant, modified sulcus bleeding index, plaque index, marginal bone loss, complications, reason of implant failure, and inference by the study author. Data was initially retrieved from two papers and presented in a pilot sheet, which was then approved by an expert to proceed with additional data extraction. Any disagreements between the authors were settled through conversation.

Results

The database search identified 28 studies of which 20 were from PubMed search while eight articles were from Google scholar search. After screening of titles, six studies were excluded and further another six studies were excluded as they were duplicates. The remaining 16 studies were screened based on abstract of which two studies were excluded as the abstract confirmed the studies to be non-eligible for the review. The full texts of remaining 14 articles were read and a total of eight articles were excluded at this step due to reasons: virtual study (n=2), case report (n=2), study focused on ideal implant length and angulation (n=3), and analysed morphological characteristics (n=1) keeping the final count of six articles.[17-22] The characteristics of the included studies are presented in Table 2. The studies presented the below outcomes.

Survival rate

A high survival rate was reported in all the six included studies of this review. The survival rate ranged from 88.06% –100% with a mean follow-up between 11 months–10 years. The success rate was high in the initial years but decreased with the advancing years and was reported to be lowest (88.06%) at a follow-up of more than 10 years. In all the cases of failure, the major reason was lack of osseointegration.

Clinical outcomes:

The mean probing depth around the implant was 2.30±0.54 mm, sulcus bleeding as recorded by modified sulcus bleeding index was 0.13±0.40, and plaque recorded by plaque index was 1.16±0.76. These parameters were reported in only one study. The average marginal bone loss after placement of implant ranged from 0.28–1.21 mm.

Complications

Majority of the studies reported no complications like infection, edema, or wound dehiscence, bleeding, intraoperative or postoperative adverse events, pain, implant radiolucency, haemorrhage or maxillary sinus floor perforation. However, 13 patients (1.02%) out of 1,279 patients experienced complications like mucositis within four months of the surgical procedures (n=3), fractured prosthesis (n=2), chipping of ceramic (n=2), peri-implant mucositis (n=2), and mobility, bleeding or discomfort (n=4).

Discussion

The concept of pterygomaxillary region was introduced by Tulasne in the year 1992.[23] By 1989, Paul Tessier proposed an idea of placing implants in the ptegomaxillary region considering the failure of various techniques used in rehabilitation of posterior maxilla.[24]According to the authors, posterior atrophic maxilla retains around 80% of the original bone corridor, which is sufficient for placing a long implant.[25]

Radiographic evaluation of pterygomaxillary region provides useful information before planning implants in this region. The ideal process of placing an implant in the pterygoid region is through pterygoid process into the pterygoid fossa; further, the implants are placed in the middle part of the pterygoid process as it consist of the thickest bone for implant support.[12,26] Considering their long path into the bone, the length of these implant ranges from 15mm – 22mm.[19,27,28] In the present review, the pterygoid implants used in the included studies ranged from 7mm to 22mm.[17-22] The results are similar to the previous systematic review that reported the implant length between 13mm to 20mm.[15]

The survival rate of pterygoid implants in the present review was between 88.06% and 100% at a follow-up ranging from 11 months–10 years indicating that the survival rate of these implants was high in atrophic maxilla.[17-22] The highest survival rate was observed at 1 year post procedure while the least was observed at 10 years.[17,20] The primary cause of failure of implants (a small percentage though) in the included studies was discussed as lack of osseointegration. However, none of the studies included in the systematic review reported by Araujo RZ et al. (2019) provided a reason for implant failure.[15] The high survival rate of the implants can be explained by the presence of dense bone in the pterygoid region that promotes osseointegration;[29] the implant design which is longer and wider compared to conventional implants thereby providing enhanced stability and support; a secure anchorage due to surrounding bone and anatomical structure;[30] and a surgical technique which involves optimal positioning of the implants through an advanced surgical technique with careful planning and precise placement.[31] Studies have also report-

ed thorough cleaning of the oral cavity during implant surgery, removal of all necrotic tissues, and antibiotic therapy for overcoming inflammation as the attributable factors for the success of implants.[20] Nevertheless, it should be noted that apart from these factors, the survival rate also depends on patients overall health, oral hygiene, and adherence to post-operative care instructions. However, the survival rates in this review also highlight that they present a steep decrease with advancement in years.[32]

The clinical outcomes with respect to pterygoid implants were not extensively reported in the included studies. Only three studies reported about the clinical outcomes in terms of probing depth around the implants, sulcus bleeding, plaque, and marginal bone loss. The average marginal bone loss after placement of implant ranged from 0.28–1.21 mm.[18,21,22] The minimum bone loss can be attributed to the implant design, surgical technique, bone augmentation, and possibility of immediate loading.

Placing the implants at different angulation rather than straight was observed in the studies included in this review. The implants were placed in angles ranging from 25°–60°.[17,19-22] These angles are decided based on the height of tuberosity and the floor of maxillary sinus. According to the literature, tilting the posterior implants allows for the implantation of lengthier implants. As a result, the contact area between the implant and the bone expands, improving the implant's main stability. The implant support is more distal, and the space between implants is greater than when straight implants are used, resulting in a shorter or perhaps non-existent cantilever length. This improves stress distribution and optimises the implant's anteroposterior spread over the alveolar ridge.[33]

Although pterygoid implants are a reasonable treatment option in certain cases, they are linked with potential complications. It should be noted that the occurrence and severity of complications might vary based on individual patient characteristics, surgeon ability, and the specific implant system utilised.[34] In the present review, the included studies reported on the complications in 4% to 40% patients, reportedly; mucositis, peri-implant mucositis, pain, prosthetic mobility, and discomfort, chipping of ceramic, and complications with the interim prosthesis. Nevertheless, these complications were minor in nature and no major complications like massive bleeding from the maxillary artery or its branches during the surgery or other that would cause significant impact on the survival rate of the implant were witnessed by the authors in the studies.[20,21,22] Further, none of the patients experienced complication like infection, edema, bleeding, wound dehiscence, adverse events, pain, and peri-implant radiolucency in the studies reported in studies by Balshi TJ et al. (2013),[17] Curi MM et al.(2015),[18] Ardekian L et al. (2018),[19] and Signorini L et al.[20] (2020) in this review. The results of this review are in accordance with the previously reported review.[15]

None of the studies included in this review had patients with sinus floor lift or bone grafting.[17-22] Pterygoid implants are a treatment option for patients with severe maxillary atrophy, where there is significant bone loss in the posterior maxilla. The advantage of pterygoid implants is that they utilize the available dense pterygoid bone, which may still be present even in cases of severe maxillary atrophy. By anchoring the implants in this region, it is sometimes possible to avoid the need for bone grafting or sinus lift procedures, which are commonly required to augment bone height or volume in the posterior maxilla.[35] This benefit also allows rehabilitating patients with satisfactory full arch fixed maxillary prosthesis, which usually spanned from second molar to second

molar. However, it's important to note that not all patients are suitable candidates for pterygoid implants without bone grafting or sinus lift procedures.[36] The decision to perform these additional procedures depends on individual patient factors, such as the amount and quality of existing bone, the proximity of the sinuses, and the desired treatment outcome. Each case should be evaluated by an experienced oral surgeon or implant specialist who will assess the specific condition of the patient's jaw and determine the most appropriate treatment plan.

Before planning implant insertion in the posterior location, radiographic examination of the pterygomaxillary region is important. According to studies, panoramic radiographs do not give required information, and CBCT in implant design may be beneficial in assuring the success of pterygoid implants. Because of its usage in pre-surgical planning, CBCT aids in examining all planes and decreases the likelihood of complication from inappropriate implant failure. Furthermore, as compared to a CT scan, it exposes patients to less radiation.[37,38] However, it should be noted that the radiographic evaluation of the implants in the included studies of this review was either done by panoramic radiography or a CBCT with maximum studies evaluating implants via panoramic radiographs. This indicated that, inspite of the advantages of the CBCT over panoramic radiography; the preferred choice among the dentists is panoramic radiograph. The possible reasons may be due to inability to compare the grey values within the patient at different intervals or among a set of patients thereby compromising the assessment of bone density. Further, the quality of images is highly influenced by the exposure parameters.[39]

The review certainly has few limitations. The results of this review come majorly from retrospective studies (low level of evidence) and thus need to be interpreted with caution. The sample size of most of the included studies was small and the follow-up was for 1 year to 3 years with only one study reporting outcomes at 10 years follow-up.

Conclusion:

Within the limitations of this review it can be concluded that the survival rate of pterygoid implants when used in anatrophic maxilla is high. Thecomplications associated with pterygoid implants are minimal with no clinical significance. Considering the position and the angled placement of the implants in the jaw, it aids in preventing the need of bone grafting and sinus lift and yet provides a stable anchorage for survival and distribution of occlusal load. However, further studies prospective studies are recommended wit long term follow-up to assess the evidence on the survival of the implants with clinical outcomes in a long run.

References

1. Mishra S. Does modern medicine increase life-expectancy: Quest for the Moon Rabbit? Indian Heart J. 2016;68(1):19-27.
2. World Health Orgamization. Oral health. Accessed at: https://www.who.int/news-room/fact-sheets/detail/oral-health. Accessed on: 17 Jun 2023.
3. Jenny G, Jauernik J, Bierbaum S, Bigler M, Gratz KW, Rucker M, Stadlinger B. A systematic review and meta-analysis on the influence of biological implant surface coatings on periimplant bone formation. J Biomed Mater Res A. 2016;104:2898–2910.
4. Howe MS, Keys W, Richards D. Long-term (10-year) dental implant survival: A systematic review and sensitivity meta-analysis. J Dent. 2019;84:9-21.
5. Hong DGK, Oh JH. Recent advances in dental implants. MaxillofacPlastReconstr Surg. 2017;39(1):33.
6. Deeb GR, Wilson GH, Benson KJ. Dental implants. Oral and maxillofacial surgery. 2016:274.
7. Pandey C, Rokaya D, Bhattarai BP. Contemporary Concepts in Osseointegration of Dental Implants: A Review. BioMed Research International. 2022;2022.
8. Zarb GA, Schmitt A. The longitudinal clinical effectiveness of osseointegrated dental implants: the Toronto study. Part III: Problems and complications encountered. The Journal of prosthetic dentistry. 1990;64(2):185-94.
9. Fouda AAH. The impact of the alveolar bone sites on early implant failure: a systematic review with meta-analysis. J Korean Assoc Oral Maxillofac Surg. 2020;46(3):162-173.
10. Pabst AM, Walter C, Ehbauer S, Zwiener I, Ziebart T, Al-Nawas B, Klein MO. Analysis of implant-failure predictors in the posterior

maxilla: a retrospective study of 1395 implants. Journal of Cranio-Maxillofacial Surgery. 2015;43(3):414-20.
11. Korn P, Gellrich NC, Spalthoff S, Jehn P, Eckstein F, Lentge F, Zeller AN, Rahlf B. Managing the severely atrophic maxilla: Farewell to zygomatic implants and extensive augmentations?. Journal of Stomatology, Oral and Maxillofacial Surgery. 2022;123(5):562-5.
12. Nag PV, Sarika P, Bhagwatkar T, Dhara V. Pterygoid implant: Option for rehabilitation of the atrophic posterior maxilla. int J Contemp dent Med rev. 2019;2019:1-5.
13. Balaji VR, Lambodharan R, Manikandan D, Deenadayalan S. Pterygoid implant for atrophic posterior maxilla. J Pharm BioalliedSci 2017;9:S261-S263.
14. Bidra AS, Huynh-Ba G. Implants in the pterygoid region: a systematic review of the literature. International journal of oral and maxillofacial surgery. 2011;40(8):773-81.
15. Araujo RZ, Santiago Júnior JF, Cardoso CL, BenitesCondezo AF, Moreira Júnior R, Curi MM. Clinical outcomes of pterygoid implants: Systematic review and meta-analysis. J Craniomaxillofac Surg. 2019;47(4):651-660.
16. Bidra AS, Peña-Cardelles JF, Iverson M. Implants in the pterygoid region: An updated systematic review of modern roughened surface implants. Journal of Prosthodontics. 2023;32(4):285-91.
17. Balshi TJ, Wolfinger GJ, Slauch RW, Balshi SF: Branemark System implant lengths in the pterygomaxillary region: a retrospective comparison. Implant Dent. 2013;22:e610–e612.
18. Curi MM, Cardoso CL, RibeiroKde C. Retrospective study of pterygoid implants in the atrophic posterior maxilla: implant and prosthesis survival rates up to 3 years. Int J Oral Maxillofac Implants. 2015;30(2):378-83.
19. Ardekian L, Levit L, Ishabaiv R, Levit M. Pterygoid dental implants: An alternative solution for treatment of posterior atrophic maxilla. Clinical report on a series of 20 patients. World J Oral MaxillofacSurg 2018;1:1007.
20. Signorini L, Faustini F, Samarani R, Grandi T. Immediate fixed rehabilitation supported by pterygoid implants for participants with severe maxillary atrophy: 1-Year postloading results from a prospective cohort study. The Journal of Prosthetic Dentistry. 2021;126(1):67-75.
21. Nag VP, Michael L, Sarika P, Daniel S, Bhagwatkar T. Minimally Invasive Reconstruction of Atrophic Maxilla Using Novel TTPHIL Technique-A Retrospective Evaluation of Pterygoid Implants and Prosthesis Success in 75 Patients. Dent Adv Res. 2022;7:186.
22. Wu J, Liu K, Li M, Zhu ZJ, Tang CB. Clinical assessment of pterygoid and anterior implants in the atrophic edentulous maxilla: a retrospective study. Hua Xi Kou Qiang Yi XueZaZhi. 2021;39(3):286-292.
23. Tulasne JF. Implant treatment of missing posterior dentition. In: Albrektsson T, Zarb GA, editors. The Branemark Osseointegrated Implant. Chicago: Quintessence; 1989. p. 103.
24. Tulasne JF. Osseointegrated fixtures in the pterygoid region. In: Worthington P, Branemark PI, editors: Advanced Osseointegration Surgery: Applications in the Maxillofacial Region. Chicago: Quintessence; 1992. p. 182.
25. Motiwala IA, Bathina T. A Radiographic Study on Pterygoid Implants with Hamulus as a Landmark for Engaging the Pterygoid Plate-A Retrospective Study. Annals of Maxillofacial Surgery. 2022;12(2):190.
26. Graves SL. The pterygoid plate implant: A solution for restoring the posterior maxilla. Int J Periodontics Restorative Dent 1994;14:512-23.
27. Chin YP, Leno MB, Dumrongwongsiri S, Chung KH, Lin HH, Lo LJ. The pterygomaxillary junction: An imaging study for surgical information of LeFort I osteotomy. Sci Rep 2017;7:9953.
28. Salinas-Goodier C, Rojo R, Murillo-González J, Prados-Frutos JC. Three-dimensional descriptive study of the pterygomaxillary region related to pterygoid implants: A retrospective study. Sci Rep 2019;9:16179.
29. Monteiro DR, Silva EV, Pellizzer EP, Filho OM, Goiato MC. Posterior partially edentulous jaws, planning a rehabilitation with dental implants. World J Clin Cases. 2015;3(1):65-76.
30. Ren J, Shu L. Pterygoid Implant-Based "VIV" Design for Rehabilitation of Extreme Maxillary Atrophy. J Craniofac Surg. 2022;33(7):2195-2198.
31. George P, Kurtzman GM. Pterygoid Implants: Anatomical considerations and surgical placement. J Osseointegr 2022;14(2):81-87.
32. Kanathila H, Pangi A, Benakatti V, Patil S. Maintenance of dental implants: A way to long term success: A review. Int J Appl Dent Sci. 2018;4(2):104-7.
33. Cucchi A, Vignudelli E, Franco S, Ghensi P, Malchiodi L, Corinaldesi G. Evaluation of crestal bone loss around straight and tilted implants in patients rehabilitated by immediate-loaded full-arch All-on-4 or All-on-6: A prospective study. Journal of Oral Implantology. 2019;45(6):434-43.
34. Kochar SP, Reche A, Paul P. The Etiology and Management of Dental Implant Failure: A Review. Cureus. 2022;14(10):e30455.
35. Candel E, Peñarrocha D, Peñarrocha M. Rehabilitation of the atrophic posterior maxilla with pterygoid implants: a review. Journal of oral implantology. 2012;38(S1):461-6.
36. Paul T, More V, Doshi N. Prosthodontic Rehabilitation Using Pterygoid Implant. Journal of Pharmaceutical Negative Results. 2022:1046-50.
37. Khongkhunthian P, Jomjunyong K, Reichart PA. Accuracy of cone beam computed tomography for dental implant treatment planning. CMU J Nat Sci. 2017;16(1):51-62.
38. Kandasamy B, Reddy RN, Ambooken M, Jerry JJ. Assessment of Pterygomaxillary Region for Insertion of Pterygoid Implants - A Cone Beam Computed Tomography (CBCT) Study. Int J Dentistry Oral Sci. 2020;S9:02:001:1-4.
39. Jacobs R, Salmon B, Codari M, Hassan B, Bornstein MM. Cone beam computed tomography in implant dentistry: recommendations for clinical use. BMC Oral Health. 2018;18(1):88.