Zygomatic Bone: Anatomic Bases for Osseointegrated Implant Anchorage

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Purpose: *The aim of the present study was to evaluate zygomatic bone thickness considering a possible relationship between this parameter and cephalic index (CI) for better use of CI in the implant placement technique.* ***Materials and Methods:*** *CI was calculated for 60 dry Brazilian skulls. The zygomatic bones of the skulls were divided into 13 standardized sections for measurement. Bilateral measurements of zygomatic bone thickness were made on dry skulls.* ***Results:*** *Sections 5, 6, 8, and 9 were appropriate for implant anchorage in terms of location. The mean thicknesses of these sections were 6.05 mm for section 5, 3.15 mm for section 6, 6.13 mm for section 8, and 4.75 mm for section 9. In only 1 section, section 8, did mean thickness on 1 side of of the skull differ significantly from mean thickness on the other side (*$P < .001$*).* ***Discussion:*** *For the relationship between quadrant thickness and CI, sections 6 and 8 varied independently of CI. Section 5 associated with brachycephaly, and section 9 associated with subbrachycephaly, presented variations in the corresponding thickness.* ***Conclusion:*** *Based on the results, implants should be placed in sections 5 and 8, since they presented the greatest thickness, except in brachycephalic subjects, where thickness was greatest in section 5, and in subbrachycephalic subjects, where thickness was greatest in section 9. CI did not prove to be an appropriate parameter for evaluating zygomatic bone thickness for this sampling.* (More than 50 references.) INT J ORAL MAXILLOFAC IMPLANTS 2005;20:441–447

Key words: *atrophic maxilla, cephalic index, dental implants, zygomatic bone*

When treating patients with atrophic mandibular and maxillary ridges, it is not always possible to predict favorable results.[1–4] Misch[5] stated that the oral soft tissues of edentulous subjects are more sensitive to decreased salivary flow and alveolar mucosa thickness, making the conventional prosthetic restoration inefficient.

In 1965, the osseointegration concept was first used to treat an edentulous patient. A 2-stage technique[6] was used for this treatment. Initially, a modified reconstruction procedure was applied using a bone graft removed from the proximal metaphysis of the tibia and placed in the edentulous maxilla and mandible to permit placement of the implant in a second phase.[6]

Before osseointegration was developed, removable mucosa-supported prosthetic restorations presented higher difficulty levels in the mandible. The small contact area between the prosthesis and mucosa, bone trauma, muscle attachments, and mandibular movements were factors affecting prosthetic restoration.[7] With osseointegrated implants, maxillary rehabilitation is more complex because of the proximity of the maxillary sinus and nasal cavity.

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In the mandible, even with the occurrence of severe resorption, adequate residual ridge for implant placement can usually be found in the anterior region between the mental foramina.[7]

Another important factor for successful rehabilitation using osseointegrated implants is the quality of the bony tissue that will receive the implants. In the anterior mandible, type 1 or 2 bone is usually found, while, in the posterior maxilla, type 3 or 4 bone is prevalent.[8]

Approximately 20% of the population over 18 years of age presents an absence of posterior teeth in the maxillary.[5] The frequency of edentulism is 35 times higher in the posterior maxilla than in the mandible.[5] Patients with severe maxillary atrophy in addition to maxillary sinus pneumatization usually require alveolar ridge height and thickness for endosseous implant placement.[5]

Implant placement in the posterior maxilla usually requires bone grafting in the maxillary sinus floor.[9,10] This procedure can result in an increase in the osseointegration success rate when compared with the placement of implants in the maxillary bone without bone grafting. Disadvantages include needed surgical skill, increased treatment time, presence of polyps and mucoceles, the potential for the septum to be an obstacle, and risk of complications such as sinus infection and blood vessel break-up.[11–19]

Another procedure that has been used to solve the problem created by the lack of bone tissue is the pterygoid implant, which can be used to support restorations in the posterior maxilla.[20,21] The advantages of this technique are the maintenance of sinus cavity integrity and architecture, elimination of the need for bone grafting, and reduction of morbidity and treatment time compared with sinus floor elevation.[20,21] According to Graves,[20] the disadvantages are the operative skill required, difficulty obtaining the needed visual access, and small bone volume in the maxillary tuberosity region.[20,21]

The conventional procedures for reconstruction of osseous topography can result in a high morbidity rate and are time consuming and expensive. Thus, it may be possible to choose simpler and less invasive alternative surgical techniques, such the placement of implants in the zygomatic bone.[22] This procedure, which has been indicated for a growing number of subjects, aims at restoring the function of the severely resorbed posterior maxilla following ablative tumor surgery, in cleft palate patients, or following failure of grafting procedures.[23–27]

Adequate knowledge of zygomatic bone anatomy is needed for better standardization and improved use of the technique. Therefore, the aim of the present study was to evaluate the thickness of the bone, considering the discrepancy among the locations and the possible relationship between this parameter and the cephalic index (CI).

MATERIALS AND METHODS

The study was carried out on 60 dry Brazilian skulls from 37 men and 23 women ranging in age from 18 to 87 years. Zygomatic bone thickness was measured bilaterally. The skulls were the property of the Universidade Federal de São Paulo Morphology Department. They were divided into 5 groups of 12, according to Pierre Broca[28] CI:

- **Group I (Dolichocephalic):** CI less than or equal to 75.00
- **Group II (Subdolichocephalic):** CI of 75.01 to 77.77
- **Group III (Mesocephalic):** CI of 77.78 to 80.00
- **Group IV (Subbrachycephalic):** CI of 80.01 to 83.33
- **Group V (Brachycephalic):** CI of 83.34 or more

Procedures for Obtaining CI

The CIs were determined according to the Pierre Broca method, cited by Testut and Latarjet.[28] Each skull was placed on a plane, and the maximum transverse diameter was measured using 2 squares placed at the most transverse points on the right and left sides of the skull, ie, the points of maximal curvature. The procedure was repeated, taking as reference points the points of greatest anteroposterior curvature. Thus, the maximum anteroposterior diameter was obtained. The CI of each skull was defined by the following formula:

$$CI = \frac{\text{Maximum transverse diameter of the skull} \times 100}{\text{Maximum anteroposterior diameter of the skull}}$$

Measurement Procedure

The external surface of the zygomatic bone was divided into 13 sections for standardization of the thickness measurement sites. A transparent autoadhesive polyvinyl chloride (PVC) laminate placed at the external bone surface was used. Four reference points (A, B, C, and D) were marked on the laminate. The laminate was then removed, and lines linking the 4 points were drawn, resulting in a quadrilateral figure. This figure was divided into 16 sections, and those that covered the zygomatic bone when in place were numbered 1 to 13 (Fig 1).

Since this investigation was aimed at studying zygomatic bone wall thickness, focusing attention on its clinical use for implant placement and further oral rehabilitation, the sites of highest interest were those with potential for implant placement according to *The Branemark System Manual*.[17] Those sites corresponded to the sections identified as 5, 6, 8, and 9. For this reason, only those sections were used for measurements.

After drawing and identifying the sections, the laminate was re-placed on the zygomatic bone. The thicknesses of the sections of interest were obtained using a thickness gauge (ACE Brock Mass 08-000-52 stainless Germany 99p0 with 0.5 mm of approximation). The instrument tips were placed perpendicularly to the external and internal surfaces of the bone in each section, and the values were recorded. The same person performed all anatomic measurements.

Association among variables of interest was studied using the Spearman correlation coefficient.[29] To compare the right and left sides, the nonparametric Wilcoxon signed rank test was used. P was considered statistically significant if it was less than .05.

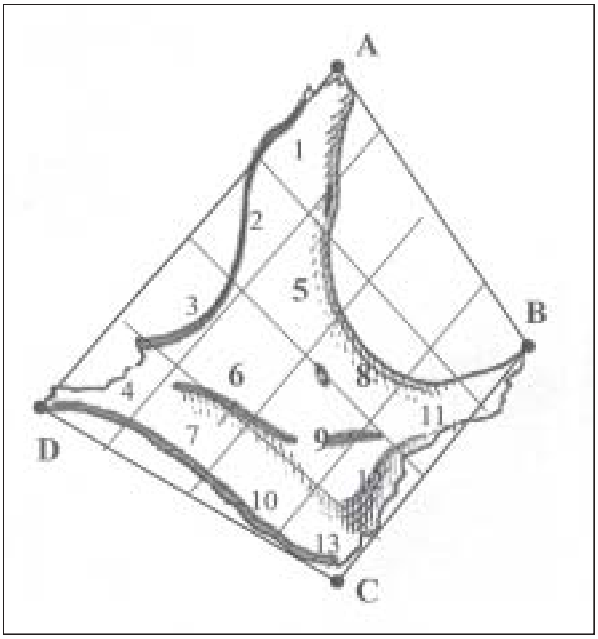

Fig 1 Drawing of the zygomatic bone. Point A articulates with the frontal zygomatic process. Point B articulates with the maxillary zygomatic process on its superior border. Point C articulates with the maxillary zygomatic process on its inferior border. Point D articulates with the temporal zygomatic process. Based on these points, a grid was formed and superimposed over the zygomatic bone, and the sections that contained a portion of the maxillary bone were labeled 1 to 13. Sections 5, 6, 8, and 9 were the sections with the best potential for implant placement.

RESULTS

For each section, the measurement made on the left zygomatic bone was compared to that made on the right zygomatic bone. As can be seen in Table 1, no significant differences were found for sections 5, 6, or 9. For section 8, there was a significant difference between the left and right zygomatic bones; the right zygomatic bone was significantly thicker ($P < .001$).

Mean Thickness with Regard to CI

As can be seen in Table 2, the highest mean thickness value for section 5 was 6.7 mm. This was the mean thickness measured on the left side for the subdolichocephalic group. The lowest value for section 5 was 5.7 mm (subbrachycephalic group, right side; mesocephalic group, left side). For section 6, the highest value was 3.8 mm (subdolichocephalic group, left side), and the lowest value was 2.4 mm (dolichocephalic group, left side; mesocephalic group, left side). For section 8, the highest value was 7.1 mm (subdolichocephalic group, right side) and the lowest was 5.4 mm (mesocephalic group, left side). For section 9, the highest value was 5.6 mm (subdolichocephalic group, right side), and the lowest was 4.1 mm (dolichocephalic group, right side).

Association Between Thickness and CI

After statistical analysis, when the thicknesses of the sections of interest were assessed for association between thickness and CI, it was concluded that sections 6 and 8 presented no significant association; thus, CI could not be used to identify possible bone thickness values for those sections.

The thicknesses of sections 5 and 9, however, presented significant associations to the brachycephalic and subbrachycephalic portions of the CI. There was an association between CI value and thickness for subbrachycephalic subjects in section 9 and brachycephalic subjects in section 5. For this population sampling, for sections 5 and 9, no other associations could be made between CI and thickness.

DISCUSSION

The use of zygomatic bone for the placement of endosseous implants for prosthetic support following ablative surgical procedures or trauma or for cleft palate patients has been previously described.[2,27,30–34] Recently, this site has also been indicated for the placement of endosseous implants in patients with severely resorbed posterior maxillae, and this technique has resulted in high success rates.[7,22–24,26,27,35–40] The objective of this procedure is to avoid complications related to reconstructive procedures such as bone grafting, since they may cause high morbidity, and such treatment can be slow and expensive.[41]

To apply this technique, it is necessary to evaluate the type of prosthetic rehabilitation and its limits, the psychologic aspects, the patient's age, maxillary sinus conditions, treatment reversibility, and anatomic limitations in the anterior and posterior maxilla.[36] Other elements that can be assessed are craniometric characteristics such as CI.

The most frequent sites for dental implant placement are the maxilla and mandible, which have been extensively studied through histomorphometry.[42–44] However, there is little information on the zygomatic bone either in articles related to implantology or in anatomy treatises.[28,45–49]

Nkenke and colleagues[38] studied the proportions of 30 zygomatic bones and found values of 19.99% ± 7.60% for trabecular bone and 83.18% ± 8.87% for cortical bone in the female group. The values for the bones from males were 27.32% ± 9.49% for trabecular bone and 83.68% ± 6.35% for cortical bone. Those authors presented mean lateral-thickness measures of 7.60 ± 1.45 mm for the bones from women and 8.00 ± 2.26 mm for the bones from men. Despite less favorable values found in the female zygomatic bone, these differences were not statistically significant.

Jensen and associates[31] examined 15 skulls from India and found a mean thickness of 4.4 mm for their zygomatic bones. Nobel Biocare zygomatic implants measure 4.5 mm in diameter and, according to Brånemark and coworkers,[6] there must be at least 1 mm of bony tissue around the implants. An important parameter for implant placement is the available bone volume, and the aforementioned data revealed critical conditions for the zygomatic bone.

To contribute to the improvement of this technique, in the present study the thickness of the zygomatic bone was measured in the locations planned for implant placement by comparing the thickness of the zygomatic bone in the sections of interest and the CI for the skull. The results of those measurements, followed by comparison between the right and left sides, demonstrated that the left and right zygomatic bones were statistically equivalent in sections 5, 6, and 9. A statistically significant difference was seen in section 8 when the left and right sides were compared; the right side was significantly thicker than the left ($P < .001$) (Tables 1 and 2).

Based on the thickness results, sections 5 and 8 are recommended for implant placement, since they presented the highest thickness values. When the zygomatic complex thickness is limited, computer-assisted implant placement can be used.[39] Based on spiral computerized tomography data, a guidance system can be installed for the preoperative planning and intraoperative control of implant placement. Presurgical planning can be assisted by 3-dimensional visualization of the anatomic sites and the virtual placement of the implants. By guiding the drills in the planned direction, the surgical procedure for implant placement can be carried out with precision.[38–40,50]

When examining a patient, appropriate craniometric measurements can be made, and patients can be categorized according to the Pierre Broca[28] classification according to the values obtained. The higher the CI, the more rounded or brachycephalic the skull is; the lower the CI, the more elongated or dolichocephalic.[28]

In the present study, effort was made to determine whether zygomatic bone thickness is associated with CI. For this sampling, no significant association between thickness and CI was found for sections 6 or 8; the thickness values varied independently of the CI. On the other hand, when sections 5 and 9 were compared, the statistical results showed a significant association between thickness in section 5 and the brachycephalic range of the CI and a significant association between thickness in section 9 and the subbrachycephalic range of the CI. The highest and lowest CI values corresponded with the highest and lowest thicknesses for both sections. When, for example, a high CI measurement (ie, in the brachycephalic range) was found, a corresponding value could be expected for thickness of the zygomatic bone in section 5. The same could be expected for thickness of the zygomatic bone in section 9 in subbrachycephalic subjects (Table 3).

Success rates of 65% to 75% were described when the zygomatic bone alone was used as anchorage for reconstruction after ablative surgery and trauma from several origins.[33,35,51] When zygomatic implants were placed in normal patients presenting with severely resorbed maxillae, the success rate was more than 80%.[22,23]This high rate was apparently related to the fact that in these cases the palatal alveolar bone ridge and the sinus floor become part of the anchorage areas for these implants.[22,23] High success rates can be projected when 4 cortical bone walls are used for anchorage, in comparison to the 1 or 2 used for conventional implant placement in the maxilla. The use of as many cortical bone walls as possible has been defended as a decisive factor in determining the success of dental implants, since this provides greater stability than the presence of a large quantity of trabecular bone tissue.[52,53]

It has been suggested by Jensen and coworkers[31] that zygomatic implants can be made even more stable if they are placed inside the infratemporal fossa, thereby obtaining support from 2 additional cortical bone walls. Although the muscles in the infratemporal fossa may be at risk of perforation, according to

Table 1 Mean Thickness in mm of the Studied Sections of the Zygomatic Bone

	Section							
	5R	5L	6R	6L	8R	8L	9R	9L
Minimum	1.0	2.5	1.0	1.0	2.5	2.0	2.0	2.0
Maximum	11.0	9.0	6.0	7.0	11.0	9.0	8.0	8.5
Median	6.0	6.0	3.0	3.0	7.0	6.0	4.5	5.0
Mean	6.1	6.0	3.0	2.8	6.5	5.8	4.7	4.8
SD	1.9	1.5	1.2	1.1	1.8	1.4	1.6	1.6
Spearman correlation coefficient	0.36		1.5		4.1		-0.89	
P	>.05		>.05		<.001		>.05	

Table 2 Mean Thickness in mm by Group of the Sections Studied

	Section							
Group	5R	5L	6R	6L	8R	8L	9R	9L
Dolichocephalic	5.9	5.8	2.6	2.4	6.5	5.8	4.1	4.7
Subdolichocephalic	6.5	6.7	3.6	3.8	7.1	6.4	5.6	5.4
Mesocephalic	5.8	5.7	2.8	2.4	6.5	5.4	4.6	4.6
Subbrachycephalic	5.7	6.0	3.4	2.8	5.9	5.7	4.5	4.5
Brachycephalic	6.5	5.8	2.7	2.8	6.4	5.6	4.7	5.0

Table 3 Significance Analysis of Association Between Sections of Interest and Respective CI Groups

	- Dolichocephalic	Subdolicho-cephalic	Mesocephalic	Subbrachy-cephalic	Brachy-cephalic
Segment 5 × CI	0.33	0.19	0.08	0.04	0.52*
Segment 6 × CI	0.01	0.37	0.34	0.18	0.20
Segment 8 × CI	0.11	0.46	0.13	0.27	0.28
Segment 9 × CI	0.03	0.10	0.19	0.54*	0.05

* $P < .05$. For all other values, $P > .05$.

Jensen and associates, complications or sequelae originating from this procedure were not found.

CONCLUSIONS

1. Despite the unfavorable structure of the zygomatic bone, implants can be placed in patients after ablative surgical procedures or trauma, in cleft palate patients, patients with severely resorbed maxillae, or following failed grafting procedures with good clinical success when it is possible to achieve multicortical stabilization.
2. Thickness measures showed that sections 5 and 8 were the most appropriate areas for implant placement in selected Brazilian dry skulls.
3. For this population sampling, CI did not prove to be an adequate parameter for determining zygomatic bone thickness values, except for brachycephalic and subbrachycephalic subjects, for sections 5 and 9, respectively.

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REFERENCES

1. Parel SM, Holt R, Brånemark P-I, Tjellström A. Osseointegration and facial prosthetics. Int J Oral Maxillofac Implants 1986;1:27–29.
2. Granström G, Jacobsson M, Tjellström A. Titanium implants in irradiated tissue: Benefits from hyperbaric oxygen. Int J Oral Maxillofac Implants 1992;7:15–25.
3. Desjardins RP. Prosthesis design for osseointegrated implants in the edentulous maxilla. Int J Oral Maxillofac Implants 1992;7:311–320.
4. Balshi TJ, Lee HY, Hernandez RE. The use of pterygomaxillary implants in the partially edentulous patient: A preliminary report. Int J Oral Maxillofac Implants 1995;10:89–98.
5. Misch CE. Implantes Dentàrios Contemporâneos, ed 2. São Paulo, Brazil: Santos Livraria Editora, 2000:3-12.
6. Brånemark P-I. Introduction to osseointegration. In: Brånemark P-I, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:11–76.
7. Nary HF, Ilg JP. Atrofia severa da maxila. In: Dinato JC, Polido, WD. Implantes osseointegrados cirurgia e prótese. São Paulo, Brazil: São Paulo Artes Médicas, 2001:343–372.
8. Lekholm U, Zarb GA. Patient selection and preparation. In: Brånemark P-I, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence,1985:199–209.
9. Wood RM, Moore DI. Grafting of the maxillary sinus floor with autogenous bone prior to implant placement. Int J Oral Maxillofac Implants 1988;3:209–214.
10. Nevins M, Fiorinelli JP. The maxillary sinus floor augmentation procedures to support implant prostheses. In: Nevins M, Mellonig JT. Implant Therapy: Clinical Approaches and Evidence of Success, vol II. Chicago: Quintessence, 1998:171–195.
11. Kahnberg KE, Nyström E, Barttholdsson L. Combined use of bone grafts and Brånemark fixtures in the treatment of severely resorbed maxillae. Int J Oral Maxillofac Implants 1989;4:297–304.
12. Small S, Zinner ID, Panno FV, Shapiro HJ, Stein JI. Augmenting the maxillary sinus for implants: Report of 27 patients. Int J Oral Maxillofac Implants 1993;8:523–528.
13. Wallace SS, Froum SJ, Tarnow DP. Histologic evaluation of sinus elevation procedure: A clinical report. Int J Periodontics Restorative Dent 1996;16:47–52.
14. Lekholm U, Wannfors K, Isaksson S, Adielsson B. Oral implants in combination with bone grafts. A 3-year retrospective multicenter study using the Brånemark implant system. Int J Oral Maxillofac Surg 1999;28:181–187.
15. Keller EE, Tolman DE, Eckert SE. Surgical-prosthodontic reconstruction of advanced maxillary bone compromise with autogenous onlay block bone grafts and osseointegrated endosseous implants: A 12-year study of 32 consecutive patients. Int J Oral Maxillofac Implants 1999;14:197–209.
16. Keller EE, Tolman DE, Eckert SE. Maxillary antral-nasal inlay bone graft reconstruction of compromised maxilla: A 12-year retrospective study. Int J Oral Maxillofac Implants 1999;14:707–721.
17. Brånemark P-I, Engstrand P, Nilsson P, Svensson B, Öhrnell LO. Zygoma fixture clinical procedures. In: Idé SG, Tryck AB (eds) Brånemark System Manual. Göteborg, Sweden: Nobel Biocare, 2000:4–27.
18. Petruson B. Sinuscopy in patients with titanium implants in the nose and sinuses. Scand J Reconstr Surg Hand Surg 2004;38:86–93.
19. Jensen OT, Shulman LB, Block MS, Iacomo VJ. Report of the Sinus Consensus Conference of 1996. Int J Oral Maxillofac Implants 1998;13(suppl):11–32.
20. Graves SL. The pterygoid plate implant: A solution for restoring the posterior maxilla. Int J Periodontics Restorative Dent 1994;14:513–523.
21. Reiser GM. Implant use in the tuberosity, pteygoid, and palatine region: Anatomic and surgical considerations. In: Nevins M, Mellonig JT. Implant Therapy: Clinical Approaches and Evidence of Success, vol II. Chicago: Quintessence, 1998:197–207.
22. Darle C. The zygomaticus fixture: A new procedure for rehabilitating the severely resorbed maxilla. In: Skandia Tryckeriet AB Brånemark System Manual (ed). Göteborg, Sweden: Nobel Biocare, 2000:3–17.
23. Stella JP, Warner MR. Sinus slot technique for simplification and improved orientation of zygomaticus dental implants: A technical note. Int J Oral Maxillofac Implants 2000;1:889–893.
24. Bedrossian E, Stumpel LJ III. Immediate stabilization at stage II of zygomatic implants: Rationale and technique. J Prosthet Dent 2001;86:10–14.
25. Sloan JA, Tolman DE, Anderson JA, Sugar AW, Wolfaardt JF, Novotny P. Patients with reconstruction of craniofacial or intraoral defects: Development of instruments to measure quality of life. Int J Oral Maxillofac Implants 2001;16:225–245.
26. Balshi TJ, Wolfinger GJ. Treatment of congenital ectodermal dysplasia with zygomatic implants: A case report. Int J Oral Maxillofac Implants 2002;17:277–281.
27. Brånemark P-I, Gröndahl K, Öhrnell LO, et al. Zygoma fixture in the management of advanced atrophy of the maxilla: Technique and long-term results. Scand J Reconstr Surg Hand Surg 2004;38:70–85.
28. Testut L, Latarjet A. Tratado de anatomia humana. Madrid, Spain: Salvat Editores, 1951:225–258.
29. Zar JH. Biostatistical Analysis, ed 4. Upper Saddle River, NJ: Prentice Hall, 1999.
30. Block MS, Guerra LR, Kent JN, Finger IM. Hemimaxillectomy prosthesis stabilization with hydroxylapatite coated implants: A case report. Int J Oral Maxillofac Implants 1987;2:111–113.
31. Jensen OT, Brownd C, Blacker J. Nasofacial prostheses supported by osseointegrated implants. Int J Oral Maxillofac Implants 1992;7:203–211.
32. Izzo SR, Berger JR, Joseph AC, Lazow SK. Reconstruction after total maxillectomy using an implant-retained prosthesis: A case report. Int J Oral Maxillofac Implants 1994;9:593–595.
33. Roumanas E, Nishimura R, Beumer J III, Moy P, Weilander M, Lorant J. Craniofacial defects and osseointegrated implants: Six-year follow-up report on the success rates of craniofacial implants at UCLA. Int J Oral Maxillofac Implants 1994;9:579–585.
34. Evans HJ, Schweiger JW, Wright RF. Craniofacial osseointegration of a large midfacial bone-anchored combination maxillofacial prosthesis: A clinical report. J Prosthet Dent 1996;75: 483–486.
35. Weischer T, Schettler D, Mohr C. Titanium implants in the zygoma as retaining elements after hemimaxillectomy. Int J Oral Maxillofac Implants 1997;12:211–214.
36. Nary HF, Francischone CE, Sartori IAM. Considerações sobre o uso da fixação zigomática no tratamento de maxilas atróficas. In: Gomes LA. Implantes Osseointegrados – Técnica e Arte. São Paulo, Brazil: Santos Livraria Editora, 2002:142–155.
37. Bedrossian E. The zygomatic implant: Preliminary data on treatment of severely resorbed maxillae. A clinical report. Int J Oral Maxillofac Implants 2002;17:861–865.
38. Nkenke E, Hahn M, Lell M, et al. Anatomic site evaluation of the zygomatic bone for dental implant placement. Clin Oral Implants Res 2003;14:72–79.

39. Van Steenberghe D, Malavez C, Cleynenbreugel JV, et al. Accuracy of drilling guides for transfer from three-dimensional CT-based planning to placement of zygoma implants in human cadavers. Clin Oral Implants Res 2003;14:131–136.
40. Vrielinck L, Politis C, Schepers S, Pauwels M, Naert I. Image-based planning and clinical validation of zygoma and pterygoid implant placement in patients with severe bone atrophy using customized drill guides. Preliminary results from a prospective clinical follow-up study. Int J Oral Maxillofac Surg 2003;32:7–14.
41. Lundgren S, Rasmusson L, Sjöström M, Sennerby L. Simultaneous or delayed placement of titanium implants in free autogenous iliac grafts. Histological analysis of bone graft-titanium interface in 10 consecutive patients. Int J Oral Maxillofac Surg 1999;28:31–37.
42. Adell R, Lekholm U, Rockler B, Brånemark P-I. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981;10:387–416.
43. Brånemark P-I, Hansson BO, Adell R, et al. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. Scand J Plast Reconstr Surg 1977;16(suppl):1–132.
44. Razavi R, Zena RB, Khan Z, Gould AR. Anatomic site evaluation of edentulous maxillae for dental implant placement. J Prosthodont 1995;4:90–94.
45. Chiarugi G. Istitizioni di Anatomia Dell´Uomo. Milan, Italy: Società Editrice Libraria, 1965:617–619.
46. Crèpy C. Anatomie cervico faciale. Paris: Masson et cie Editeurs 1967:112–117.
47. Rouvière H. Anatomia humana descriptiva, topografica y funcional. Barcelona, Spain: Casa Editorial Bailly-Bailliere, 1970:91–93.
48. Parfitt AM, Mathews HE, Villanueva AR, Kleerekoper M, Frame B, Rao DS. Relationships between surface, volume, and thickness of iliac trabecular bone in aging and osteoporosis. Implications for the microanatomic and cellular mechanisms of bone loss. J Clin Invest 1983;72:1396–1409.
49. Klemetti E, Vainio P. Effect of bone mineral density in skeleton and mandible on extraction of teeth and clinical alveolar height. J Prosthet Dent 1993;70:21–25.
50. Verstreken K, Cleynenbreugel JV, Marchal G, Naert I, Suetens P, van Steenberghe D. Computer-assisted planning of oral implant surgery: A three-dimensional approach. Int J Oral Maxillofac Implants 1996;11:806–810.
51. Brånemark P-I, Higuchi KW, Oliveira MF. Rehabilitation of complex cleft palate and craniomaxillofacial defects: The challenge of Bauru. Chicago: Quintessence, 1999:29–93.
52. Ivanoff CJ, Sennerby L, Lekholm U. Influence of mono- and bicortical anchorage on the integration of titanium implants. A study in the rabbit tibia. Int J Oral Maxillofac Surg 1996;25:229–235.
53. Nakai H, Okazaki Y, Ueda M. Clinical application of zygomatic implants for rehabilitation of the severely resorbed maxilla: A clinical report. Int J Oral Maxillofac Implants 2003;18:566–570.