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Immediate implant and rehabilitation based on All-on-4 concept in patients with generalized aggressive periodontitis: A medium-term prospective study

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Abstract

Background: Aggressive periodontitis renders a great challenge to the conventional implant due to the risks of infection and ongoing marginal bone loss (MBL). A study about full-arch immediate implant and restoration in patients with advanced generalized aggressive periodontitis (GAP) was not read, even though the All-on-4 concept has been proven to be predictable for edentulous patients.

Purpose: This prospective study aimed to evaluate the feasibility and medium-term outcomes of immediate implant and rehabilitation based on the All-on-4 concept in patients with advanced GAP via clinical and radiographic analyses.

Materials and Methods: Seventeen patients (mean age 39.4 years) with advanced GAP received immediate postextraction implant and rehabilitation based on the All-on-4 concept between January 2009 and January 2014. Eighty implants were inserted into 20 arches (7 maxillae and 13 mandibles). The average follow-up duration was 5 years (range 2-7). Complications, probing depth, and plaque, bleeding, and gingiva indices were evaluated. MBL was measured based on the panoramic radiographs taken immediately after surgery and annually thereafter.

Results: The cumulative survival rate (CSR) of the implants was 98.75% (79/80) after an average of 5 years. One tilted implant failed due to peri-implantitis. The average peri-implant MBL was 0.8 ± 0.4 and 1.2 ± 0.3 mm after 1 and 7 years, respectively. The CSR was 100% (20/20) for definite prostheses, while 85% (17/20) for provisional prostheses. The average probing depth, and plaque, bleeding, and gingiva indices at the last recall visit were 3.0 ± 0.5, 1.2 ± 0.4, 0.5 ± 0.5, and 0.4 ± 0.4 mm, respectively. Patient showed high satisfaction to the overall effects.

Conclusions: Based on this study, the All-on-4 concept provided predictable outcomes in patients with GAP in 2- to 7-year follow-ups, and averted the severe bone defect area of aggressive periodontitis.

KEYWORDS
All-on-4, generalized aggressive periodontitis, immediate implant, immediate rehabilitation

1 | INTRODUCTION

Aggressive periodontitis is a destructive disease characterized by rapid progression of attachment loss and alveolar bone destruction in systemic healthy individuals, early onset age, high tendency of relapse, and familial aggregation.[1] Generalized aggressive periodontitis (GAP) exhibits involvement of at least three teeth other than first molars and incisors. The prevalence of aggressive periodontitis ranges from 1% to 15% depending on age and race.[2–4]

Some GAP patients procrastinate to access appropriate periodontal treatment until the disease has reached an advanced stage, which results in the loss of many teeth or the compromised preservation of the remaining teeth. These results in an insufficient number of teeth needed to retain fixed prostheses or removable partial dentures at a very young age.

Many clinicians hesitate to perform conventional or immediate implant and restoration treatment in GAP patients in fear of the risk of infection and uncontrolled ongoing bone loss. There is a controversy about whether implant treatment in GAP patients has increased the incidence of peri-implantitis and implant loss. The prospective studies by Mengel et al. have shown that in partially edentulous patients treated for aggressive periodontitis, implant survival rates were 97.4% to 100% in the short-term[5–7] and 83.3% to 96% in the long-term,[8,9] including implants placed in augmented bone. The compromise was that the bone and attachment loss at the implants as well as the rate of peri-implantitis, and mucositis were higher than in periodontally healthy subjects, and the implant survival rate was lower.[5–9]

Additionally, the All-on-4 protocol has been proven in several studies to be a predictable procedure for edentulous and immediate post-extraction patients.[10–16] Nevertheless, a study about full-arch immediate implant and rehabilitation based on All-on-4 concept in patients with advanced GAP was not read.

This prospective study aimed to evaluate the feasibility and outcomes of immediate implant and immediate rehabilitation based on All-on-4 concept in patients with advanced GAP via clinical and radiographic analyses, including survival rate of implants and prostheses, marginal bone loss (MBL), periodontal parameters, and complications in 2- to 7-year follow-ups.

2 | MATERIALS AND METHODS

This clinical study was performed in the Department of Oral Implantology, Peking University School and Hospital of Stomatology and was started in the year 2008. Seventeen patients (10 men and 7 women; mean age 39.4 years, ranging from 28 to 45 years at the time of implant placement) with advanced GAP were consecutively enrolled in the study between January 2009 and January 2014. A total of 20 arches were treated according to the All-on-4 concept. Each patient was informed of the purpose of the study, associated details of the procedures, and alternative treatments (eg, complete dentures) and signed a written informed consent form prior to the start of the treatment. The investigation was conducted according to the principles embodied in the Helsinki Declaration for biomedical research involving human subjects. The study protocol was approved by the local ethics committee and Beijing Health Bureau (No. 2008-9). The study was sponsored by grants from the capital health research and development of special (2014-2-4103).

Patients included in the study met all of the following inclusion criteria:

1. A diagnosis of GAP by a periodontologist according to the modified criteria proposed by CDC/AAP (2007) based on case history, clinical examination, and radiographic evaluation of attachment levels.[17,18]
2. The remaining teeth required to be extracted based on the criteria proposed by Carranza et al. (2006).[19–21]

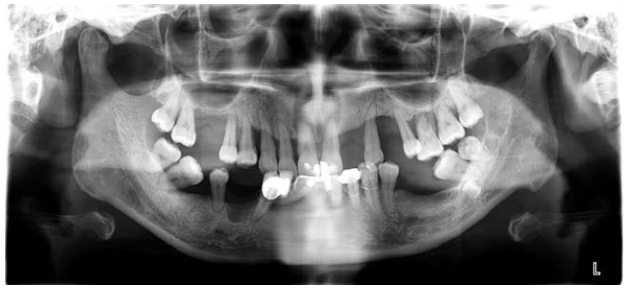

FIGURE 1 Preoperative panoramic radiograph of a GAP patient

3. Patient's age >18 years, and the onset age of aggressive periodontitis ≤30 years.
4. Physical and psychological healthy to undergo surgical and restorative procedures of the All-on-4 protocol.
5. Adequate amount of bone volume for placement, ≥4 mm wide horizontally and ≥10 mm high vertically for anterior areas.
6. Sufficient primary stability of implant with a final insertion torque >35 N·cm.

Patients were excluded if they fulfilled any of the following exclusion criteria:

1. History of systemic disease (eg, diabetes or hematologic diseases).
2. Severe parafunctional habits (eg, bruxism or clenching).
3. History of metabolic bone disease or bisphosphonate therapy.
4. History of radiotherapy or chemotherapy in the head and neck region.
5. Heavy smokers with a daily consumption of >15 cigarettes.
6. Pregnancy or lactation.
7. Lack of compliance.

2.1 | Preoperative evaluation

Clinical examinations of each patient, prior to implant surgery, were conducted to assess the size and shape of the arch, maxillomandibular relationship, vertical distance between the alveolar ridge and occlusal plane, maximum smile line, and lip support. Routine panoramic radiographs were taken to evaluate the vertical volume and quality of alveolar bones, as well as related important anatomical structures, such as mandibular nerve, mental foramen, and maxillary sinus. Cone beam computed tomography (CBCT) was obtained when some anatomical structures needed to be further identified and assessed (Figure 1).

2.2 | Peri-operative medications

Prophylactic antibiotics were prescribed ahead of the surgeries. Cefuroxime Axetil tablets (500 mg) and Tinidazole tablets (1000 mg) were administered 0.5-1 hours prior to surgery. Patients continued to take Cefuroxime Axetil tablets 250 mg twice daily for 7 days and Tinidazole tablets 500 mg daily for 5 days postoperatively. If patients were allergic

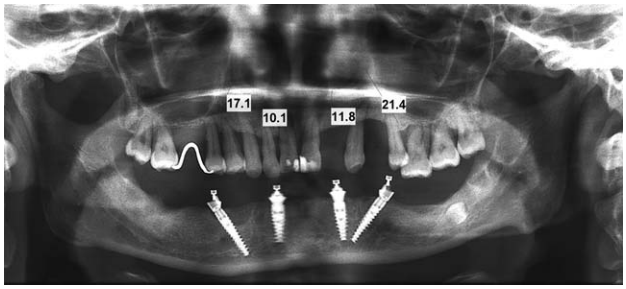

FIGURE 2 Panoramic radiograph immediate after mandibular surgery

to Cefuroxime Axetil, they were prescribed Roxithromycin. The patients were also advised to rinse with a 0.2% Chlorhexidine solution for 1 minute three times, 30 minutes before the surgery and continued after surgery for 7 days (3 times daily after meal). Analgesics (Ibuprofen tablets, 300 mg, orally) were given on the day of surgery and for 3 days postoperatively when necessary. Cortisone medication (Dexamethasone tablets, 1.5 mg) was given to relieve swelling and control inflammatory response on the day of surgery and daily for 2 days postoperatively when necessary.

The surgical procedures were performed under local anesthesia with 4% Articaine chlorhydrate and Epinephrine tartrate (1:100 000) Injection (Dentaires Pierre Rolland, Merignac, France) administered in both block and infiltration technique.

2.3 | Surgical procedures

The remaining teeth were extracted in a minimally invasive way. The alveolar sockets were thoroughly debrided to remove any granulation tissue remnants by means of curettage, and were alternately rinsed with 3% H_2O_2 and 0.2% Chlorhexidine. The sharp alveolar crests and socket prominences were removed with rongeur, while an 8-mm bur was further used to flatten the alveolar ridge to obtain a favorable vertical distance for a better esthetic result. Excess soft tissues were trimmed after bone reduction.

After this, the implants were inserted following the manufacturer's standard guidelines with a modification of the drilling sequence. Underpreparation was routinely applied to achieve maximal apical anchorage and to enhance the initial stability in cases with low bone density.

Two anterior implants were axially oriented perpendicular to the occlusal plane and parallel to the midline of the arch, and typically placed in the lateral incisor region. Two posterior implants were distally tilted by 30°-40° relative to the occlusal plane, with the emergence of the implant platform typically at the second premolar regions. The region between two sockets was the first preference for an implant placement, and the implant platform was positioned at the bone level. All the implants reached a final insertion torque >35 N·cm to ensure sufficient primary stability for immediate function, and the maximum torque achieved was 45 N·cm.

In the mandible, the mental foramens with anterior loops of mental neurovascular bundles were used to determine the positioning of the posterior tilted implants.

In some cases, the distal bone level was higher than the mesial bone level around titled implants, so the excessive distal bone was trimmed around the implant neck to ensure that the abutment was seated completely in position.

To achieve a relative parallel common insertion path so that the rigid prosthesis would seat in a passive manner, 17° or 30° angulated abutments were selected for the posterior tilted implants and straight or angulated (17° or 30°) abutments were applied to the anterior upright implants. The abutments were secured with a torque of 35 N·cm and 15 N·cm for straight and angulated abutments, respectively.

The flaps were closed and sutured with 4-0 absorbable sutures (Vicryl Rapide, Ethicon, Johnson & Johnson, Livingston, UK).

All the surgeries were performed by an experienced clinician under direct vision without using surgical guide.

A panoramic radiograph and/or CBCT was taken immediately after the surgery to verify the positions of implants and abutments (Figures 2 and 3).

2.4 | Prosthetic procedures

After the surgery, open-tray multiunit impression transfer copings (Nobel Biocare, Gothenburg, Sweden) were fastened to the abutments with screws and connected with self-curing composite resin materials (DMG, Hamburg, Germany). The pick-up technique was used to take impressions with silicone elastomeric material. Vertical dimensions were recorded and bite registrations were taken after removing the impression transfer copings.

Provisional full-arch heat-cured acrylic resin prostheses (Heraeus Kulzer, Hanau, Germany) without metal frameworks were manufactured at the dental laboratory and delivered to the patients approximately 6 hours after surgery. Provisional prostheses were comprised of 10-12 units depending on the emerging positions of the posterior implants, to guarantee a cantilever length of less than 8 mm (Figures 4–8).

The centric and lateral contacts were assessed with 40-μm articulating paper (Bausch Articulating Paper, Nashua, NH) and adjustments were made if necessary. The principles of occlusal adjustment are as follows: (1) achieving maximum occlusal contact in the implant-supported area in centric relation; (2) multipoint contact during lateral and protrusive movements; (3) canine guidance; (4) no occlusal contact with distal cantilever area in any position.

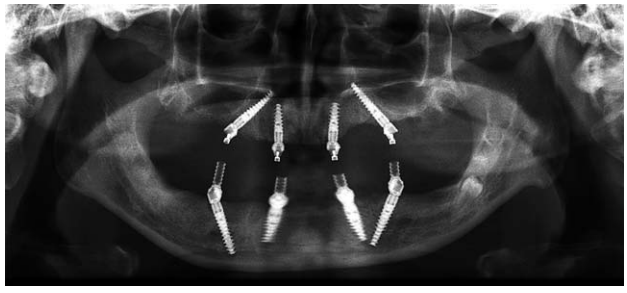

FIGURE 3 Panoramic radiograph immediate after maxillary surgery

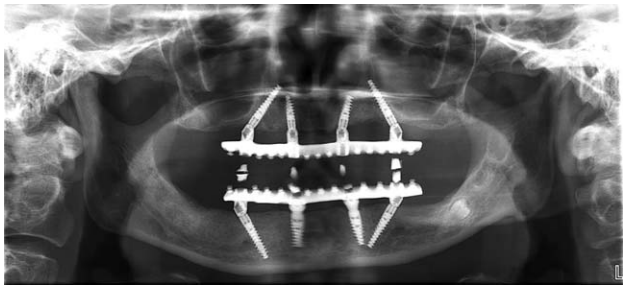

FIGURE 4 Intraorally frontal view after immediate implant and restoration of the mandible

A cold or room-temperature soft diet for the first 24 hours following surgery was recommended, followed by a semisolid diet for the next 3 months. Verbal and written oral hygiene instructions were given to the patients with emphasis on no brushing or rinsing for the first 24 hours postsurgery. Antibiotics and analgesics as listed in the perioperative medications were prescribed.

After 4-6 months, if the clinical examination indicated no signs of pain, inflammation or mobility, and the radiographic check showed absence of radiolucency around implants and good osseointegration, the final prostheses were delivered to the patients by standard All-on-4 procedures. The definitive prosthesis commonly consisted of a high-precision CAM metal framework (Nobel Biocare) with a wrap-around heat-cured acrylic resin (Heraeus Kulzer high-impact acrylic), as well as 12 acrylic resin teeth units (Heraeus Kulzer), or all-ceramic crown units (Procera Nobel Rondo ceramics). The tissue surface of the prosthesis was designed in "head to head" close contact with the alveolar ridge to ensure convenient and adequate oral hygiene maintenance (Figures 9–12).

All the restorations were performed by 2 clinicians, and fabricated by 1 technician.

2.5 | Follow-up and maintenance

All the patients were scheduled for the first control visit 1 week after immediate loading. Further follow-up visits were scheduled every 3-6 months for the first year, and on an annual basis thereafter, for up to 7 years. Detailed postloading instructions were given to the patients including how to use the dental floss and interdental brush. Patients received periodontal treatment as necessary during the maintenance periods.

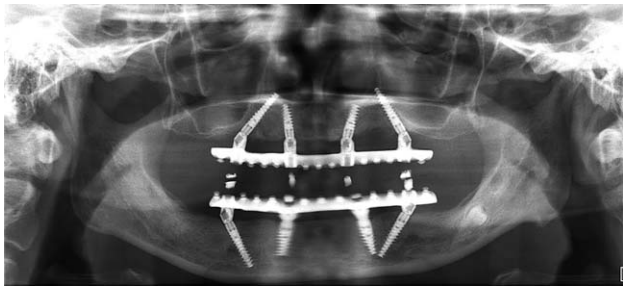

FIGURE 5 Intraorally occlusal view of the mandibular provisional prosthesis

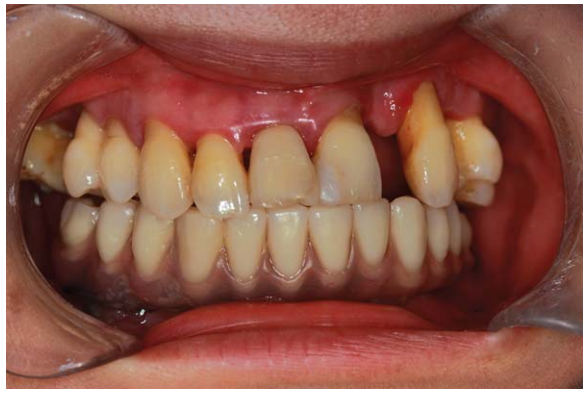

FIGURE 6 Intraorally occlusal view of the maxillary provisional prosthesis

Panoramic radiographs were obtained for the annual follow-up visits (Figures 13 and 14). The plaque index, probing depth, bleeding index, gingival index, and complications were recorded at every follow-up visit. A questionnaire was used to evaluate self-perceived factors related to comfort, aesthetics, masticatory, and phonetic functions.

2.6 | Outcome measures

Treatment outcome measures included the following parameters.

2.6.1 | Implant survival rate

The survival of an implant was determined according to a combination of modified Albrekesson criteria[22] and Malo Clinic criteria[10]:

1. Absence of peri-implant radiolucency.
2. No signs of persistent infection, pain, numbness and paraesthesia of lower lip and chin, or ongoing pathological processes such as fistula or abscess at the implant site.
3. Clinical stability of individual implant assessed with prosthesis removed after functional loading.
4. No fracture of any structure of the implant.

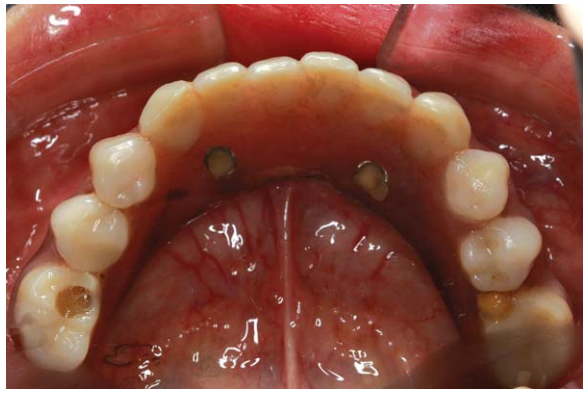

FIGURE 7 Intraorally frontal view of the provisional prostheses of both jaws

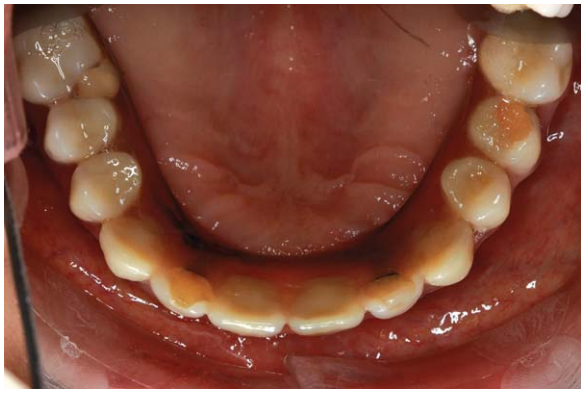

FIGURE 8 Frontal view after immediate restoration

2.6.2 | Prosthesis survival criteria

A prosthesis was considered as survival if it was in function and in absence of fracture, mobility, and pain. A prosthesis was considered to be failed if it was removed for any reason. Prosthesis stability was tested by means of two opposing instruments' pressure.

2.6.3 | Complications

Complications were divided into implant-related and prosthesis-related complications.

Biological complications were mainly implant-related complications in nature and included pain, numbness and paraesthesia, soft tissue inflammation, sinus infection, fistula and abscess formation, and presence of peri-implantitis (defined as the presence of peri-implant pockets >4 mm and ongoing bone resorption).

Prosthetic complications consisted of 3 types:

1. Mechanical complications, involved with loosening of abutments or screws, fracture of abutments, framework or any other components of prostheses, as well as separation of artificial teeth from the denture base.
2. Esthetic complications, evaluated by patient or dentists in terms of lip support and appearance of artificial teeth, soft tissue, etc.

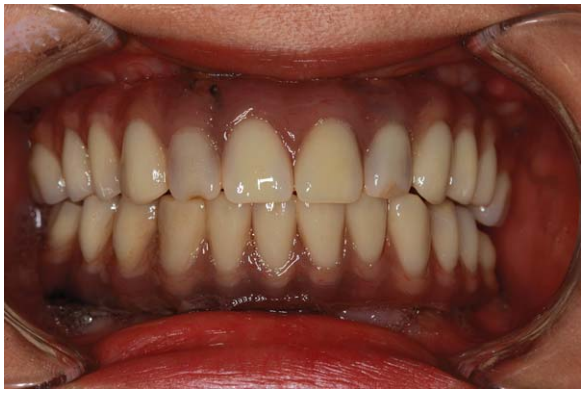

FIGURE 9 Intraorally occlusal view of the mandibular definitive prosthesis

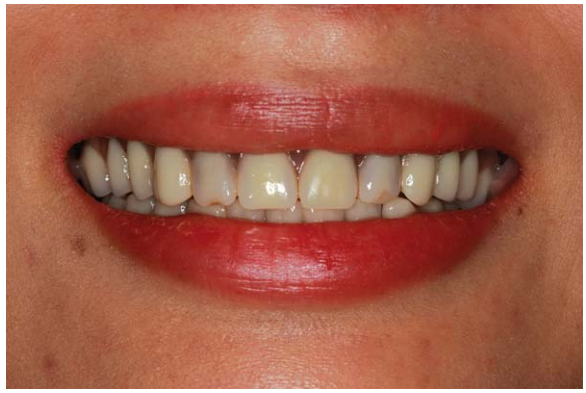

FIGURE 10 Intraorally occlusal view of the maxillary definitive prosthesis

3. Functional complications, referring to mastication dysfunction, cheek and lip biting, phonetic complaints, comfort complaints, and hygienic complaints.

2.7 | Marginal bone loss

The implant platform (the horizontal interface between the implant and the abutment) was used as the reference for each measurement; the linear distance (in millimeters) between the platform and the most coronal bone-to-implant contact was measured.[23–25]

To adjust for dimensional distortion and enlargement on the radiographs, the actual known lengths of the implants were compared to the measured implant dimensions on the radiograph. Mesial and distal values were averaged so as to have a single value for each implant.[23–25]

The image analysis software Planmeca Romexis (Planmeca Dental Imaging Oy, Helsinki, Finland) was used for measurements with an accuracy of 0.1 mm (Figure 15).

The radiographs were accepted or rejected for evaluation based on the clarity of the implant threads, because a clear thread indicates sharpness and the orthogonal direction of the radiographic beam toward the implant axis.

2.8 | Periodontal parameters

Plaque index (PI),[26] modified Sulcus Bleeding Index (mSBI),[27] and Gingival Index (GI)[26] were assessed using a scoring system ranging from 0 to

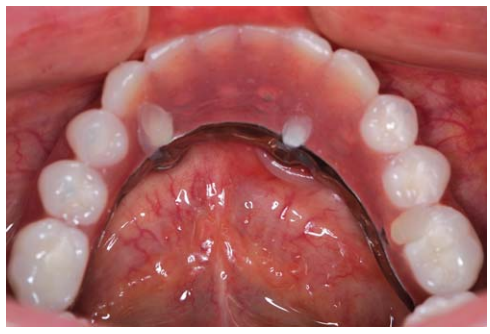

FIGURE 11 Intraorally frontal view of the definitive prostheses of both jaws

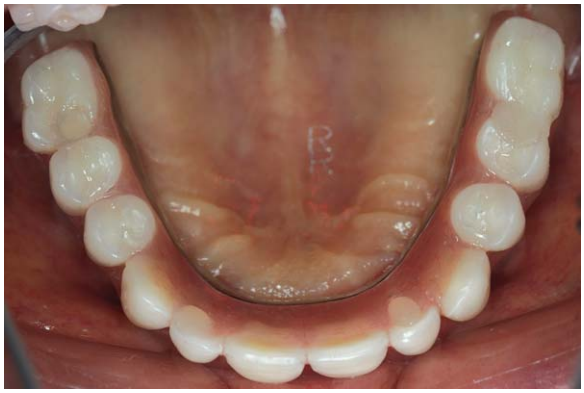

FIGURE 12 Frontal view after definitive restoration

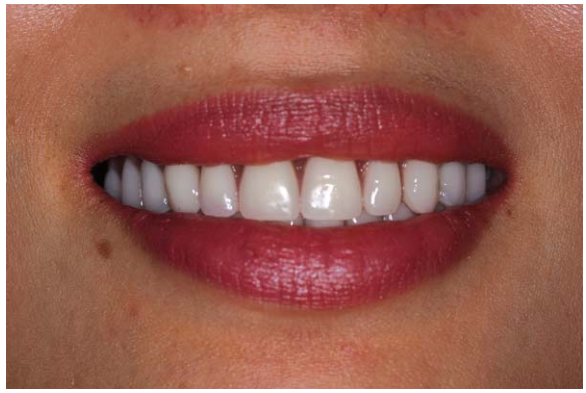

FIGURE 14 Panoramic radiograph at 3-year follow-up

3. Peri-implant probing pocket depth (PD)[17] was measured at four sites (mesial, distal, lingual, and buccal) at the follow-up examination when prostheses were removed for cleaning. The mean value of these four obtained values was calculated for each implant. The values of the last recall visit in this study (from 2 to 7 years) were used for statistical analysis.

2.9 | Statistical analysis

All the relevant data were gathered and entered into a spreadsheet (Excel 2010, Microsoft, Redmond, Wash). Cumulative implant and prosthesis survival rates were assessed using the life table analysis. Statistical analysis was carried out via software SPSS 22.0 for Windows (IBM SPSS, New York). Descriptive statistics were computed by determining mean values, standard deviations (SD), and cumulative frequencies. MBL around upright and tilted implants was compared by an independent sample *t* test. $P < .05$ was taken as the statistical significance level.

3 | RESULTS

Seventeen patients (10 men and 7 women; mean age 39.4 years, ranging from 28 to 45 years at the time of implant placement) with advanced GAP were consecutively enrolled in the study between January 2009 and January 2014, with an average of 2.8 patients per year. The mean follow-up duration was 5 years, ranging from 2 to 7 years.

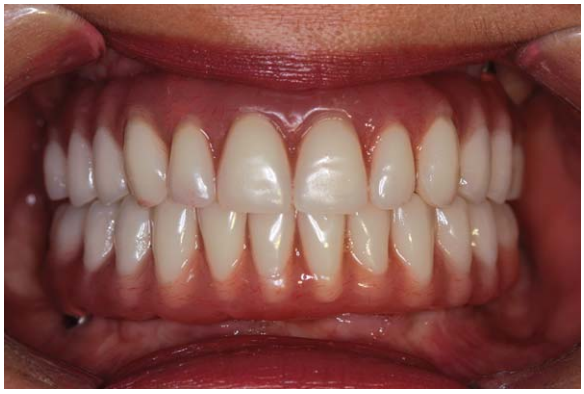

FIGURE 13 Panoramic radiograph at 1-year follow-up

The study was initiated in 2008, but there was not a patient meeting the inclusion criteria enrolled in the study until 2009.

A total of 80 implants (Branemark System MK III, Nobel Speedy Groovy, and Nobel Active; Nobel Biocare, Gothenburg, Sweden) were placed in 20 immediate postextraction jaws (7 maxillary and 13 mandibular), supporting 20 prosthesis, according to the All-on-4 protocol. Each prosthesis was supported by 4 implants. Three patients were treated in both jaws.

3.1 | Distribution of lost teeth and extracted teeth

A total of 172 teeth (including 24 third molars) were lost in 20 jaws of 17 patients with advanced GAP. The first molars were the most common teeth lost in GAP patients (17.4% of all the lost teeth), followed by the second molars (15.7%) and central incisors (12.8%). The central incisors had a more obvious dominance in the number of lost teeth in the mandible compared to the maxilla (14.3% of all the lost teeth in the mandible).

Correspondingly, a total of 148 teeth (including 16 third molars) were extracted from 20 jaws, with an average of 7.4 teeth per jaw.

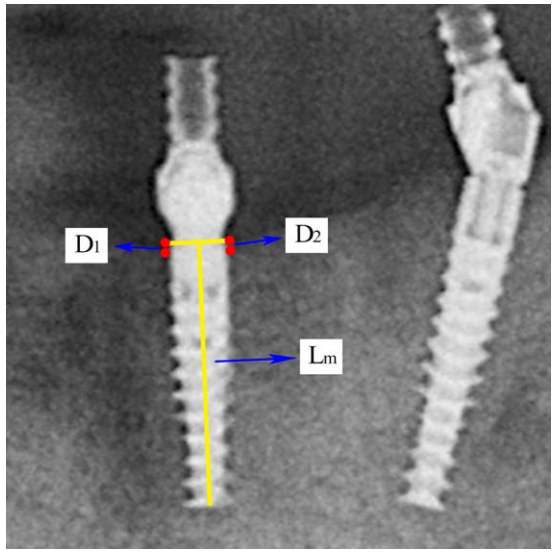

FIGURE 15 The measurement of marginal bone loss via Planmeca Romexis software based on panoramic radiograph

TABLE 1 Number of implants according to system, diameter, and length

Implant system	Implant diameter (mm)	Implant length (mm)						
		10	11.5	13	15	18	Total	
Branemark MK III	3.75	1	1	13	15	0	30	44
	4	2	0	4	4	4	14	
Nobel speedy groovy	3.5	0	0	2	0	2	4	8
	4	0	0	0	2	2	4	
Nobel active	3.5	0	0	6	10	12	28	28
Total		3	1	25	31	20	80	

Lateral incisors and canines ranked the highest in the number of teeth extracted in GAP patients, accounting for 16% of total number of extracted teeth. First premolars came next (15.5%).

3.2 | Implant placement sites

Posterior tilted implants were inserted in the site of the second premolar, the first premolar and the first molar, while anterior upright implants were placed in the site of the lateral incisor in all the 20 jaws of patients with advanced GAP. The second premolar was the most common site for posterior tilted implants (70% of all the tilted implants). Hundred percent of the anterior upright implants were inserted in the site of lateral incisor.

3.3 | Implant system, diameter, and length

The distribution of the implants classified by implant system, diameter, and length was listed in Table 1.

Of the 80 implants, 44 implants (55%) were the Branemark MK III system, 28 implants (35%) were the Nobel Active system, and the remaining 8 (10%) were the Nobel Speedy Groovy system.

Thirty-one of the 80 implants had a length of 15 mm (38.8%), which was the most often selected length. 13 mm was the most common implant length for anterior upright implant in both the maxillae and mandibles (57.1% and 57.7%). As for the posterior tilted implants, 15 mm ranked first in the maxillae (57.1%), while 18 mm ranked first in the mandibles (53.8%).

3.5 mm was the most often used diameter of the 80 implants (40%). 3.5 mm was also the top selected diameter for both upright and tilted implants in the maxillae (42.9%). Whereas, 3.75 mm ranked first for both upright and tilted implants in the mandibles (42.3%).

3.4 | Prosthetic abutment height

5 mm was the most often selected height for the abutments (21.3%) (Chart 1).

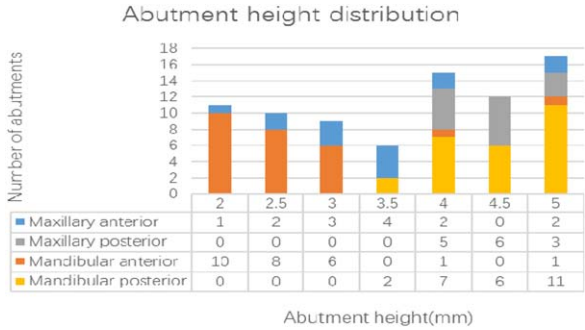

CHART 1 Distribution of prosthetic abutment height

3.5 | Implant survival rate

Only 1 posterior tilted implant (Branemark MK III, 3.5 *15 mm) in the maxilla of a 44-year-old male patient was withdrawn due to peri-implantitis at the fourth month after implant placement. A new implant was inserted 4 months later, maintaining its function for the remainder of the follow-up of this study. The cumulative survival rate (CSR) of implants in patients with advanced GAP was 98.75% (79/80) after an average of 5 years (ranging from 2 to 7 years) (Chart 2).

3.6 | Prosthesis survival rate

All definitive prostheses survived throughout the follow-ups in this study, resulting in a CSR of 100%. However, 3 provisional prostheses (2 mandibular and 1 maxillary) were fractured after loading for 2 and 3 and 5 months, respectively, thus yielding a CSR of 85%. Two of the opposite dentitions were natural teeth and 1 was All-on-4 provisional prosthesis.

For the patient with the one failed implant, the prosthesis survived on the remaining implants, while the failed implant was replaced 4 months after surgery.

3.7 | Complications

3.7.1 | Biological complications

One implant (1.25%) showed peri-implantitis (the same implant failure due to peri-implant pathology) with a pocket of 5 mm and concurrent bone loss >2 mm with bleeding on probing. It was withdrawn and reinserted with a new implant 4 months later. No further biological complications were observed (Table 2).

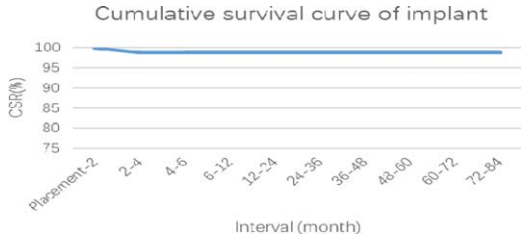

CHART 2 Cumulative survival curve of implant. CSR, cumulative survival rate

TABLE 2 Distribution of complications

Mechanical complications	Number of prostheses	Occurrence rate on provisional and definitive prostheses level
Prosthesis fracture	3	15%, 0%
Loose abutment or prosthetic screw	2	0%, 10%
Artificial teeth separation	3	15%, 0%
Functional complications	**Number of patients**	**Occurrence rate on patient level**
Phonetic problem	1	5.88%
Biological complications	**Number of implant**	**Occurrence rate on implant level**
Peri-implantitis	1	1.25%

3.7.2 | Mechanical complications

Five patients (29.4%) showed mechanical complications in provisional or definitive prostheses. Three provisional prostheses (15%, the same 3 failed prostheses) fractured in the distal cantilever area or the area close to implant coping after loading for 2 and 3 and 5 months, respectively, and new prostheses were made and delivered during the same day as the follow-up visits. Artificial teeth separation occurred in 2 mandibular and 1 maxillary provisional prostheses (15%). Loose abutment screws were observed in 2 mandibular definitive prostheses (10%). A 35-year-old female patient had both artificial teeth separation and fracture in the same mandibular provisional prosthesis. Two male patients had both fracture in provisional prosthesis and loose abutment screw in definitive prosthesis later (Table 2).

One patient (5.88%) had phonetic changes 2 weeks after surgery, and gradually overcame the problem after adaptation and phonetic practice 1 month later. No obvious masticatory problems or other functional complications were observed (Table 2).

No esthetic complications were observed in either the provisional or the definitive prostheses.

3.8 | Marginal bone loss

The average peri-implant MBL after the 1-year follow-up was 0.8 ± 0.4 mm. There was no statistical difference ($P > .05$) between the upright implants (0.8 ± 0.4 mm) and tilted implants (0.9 ± 0.4 mm). Thirty-two implants had readable radiographs after the 7-year follow-up, indicating 1.2 ± 0.3 mm and 1.2 ± 0.4 mm MBL for upright and tilted implants, respectively, also with no statistical difference ($P > .05$) (Table 3, Chart 3).

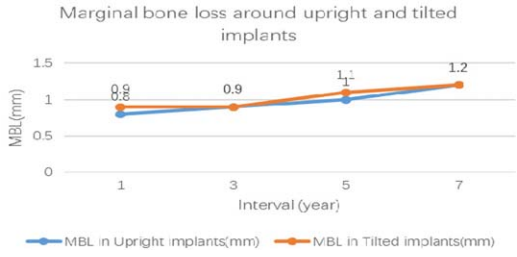

CHART 3 Marginal bone loss around upright and tilted implants

3.9 | Periodontal parameters

The mean plaque index at the last recall visit (after 2-7 years) was 1.2 ± 0.4, thus there was mild to moderate plaque accumulation around the gingival margin or adjacent abutment surface for most of the implants.

The mSBI was 0.5 ± 0.5, so there was no bleeding or isolated spot bleeding on probing for the majority of the peri-implant gingiva.

Most of the peri-implant gingiva had a normal condition or minimal inflammation with minor color change and minor edema, with an average gingiva index of 0.4 ± 0.4.

The mean peri-implant pocket depth was 3.0 ± 0.5 mm (Table 4).

3.10 | Follow-up and dropout

All patients were followed up for at least 2 years. The mean follow-up duration was 5 years (ranging from 2 to 7 years).

4 | DISCUSSION

4.1 | Controversies and challenges in correlational studies

Advanced GAP patients may have an experience of edentulism or a high mobility of the compromised remaining teeth due to rapid attachment loss and severe alveolar bone loss around the affected teeth at a very young age. Therefore, these young GAP patients may be confronted with problems of mastication, phonetics, esthetics, and social psychology throughout the 40-50 years of their long remaining life, leading to a negative effect on oral health-related quality of life.[28]

Some clinical[29] and histological studies[30,31] and systematic reviews[32,33] have shown that patients suffering from periodontal disease were successfully treated with immediate implant placement into periodontal compromised extraction sockets, provided that appropriate clinical procedures were performed before the implant placement, including meticulous cleaning, socket curettage/debridement, or chlorhexidine rinse. The main advantage of the immediate approach is the reduction of treatment duration, and the protection of the hard and soft tissue from collapse to some extent.

The All-on-4 treatment has been developed to maximize the use of available bone and preserve relevant anatomical structures without

TABLE 3 Marginal bone loss at 1, 3, 5, and 7 follow-up visits

Interval (y)	Number of implants	MBL in upright implants (mm)	MBL in tilted implants (mm)
1	80	0.8 ± 0.4	0.9 ± 0.4
3	76	0.9 ± 0.4	0.9 ± 0.4
5	44	1.0 ± 0.3	1.1 ± 0.4
7	32	1.2 ± 0.3	1.2 ± 0.4

complicated bone-grafting procedures and allows immediate function. Published data on the All-on-4 concept reported CSRs between 92.2% and 100% in edentulous and immediate postextraction patients.[10–16]

However, there is still a controversy on the implementation of dental implants in GAP patients, because of the fear of infection and uncontrolled ongoing bone loss. Lang et al suggested that such patients had poor serum antibody response to infective bacterial agents, which negatively affects the progression of the periodontitis.[34] The similarity in microbial flora responsible for aggressive periodontitis and peri-implantitis supports the perspective that periodontal pathogens may be associated with peri-implant infections and failing implants.[9,35] Further, periodontal pathogens may be transmitted from remaining natural teeth to implants, implying that periodontal pockets may serve as reservoirs for bacterial colonization around implants.[36,37] However, some positive outcomes were obtained recently.[38–43] Wu et al. reported in 2007 a patient with GAP treated with 8 implants, and indicated that the survival rate of the implants was 100% with no MBL or inflammation found in the 18-month follow-up. Author Contributions Other similar case reports also showed a positive outcome in one patient with aggressive periodontitis.[39–43] Prospective studies by Mengel et al. have shown that in partially edentulous patients treated for aggressive periodontitis, implant survival rates were 97.4% to 100% in the short-term[5–7] and 83.3% to 96% in the long-term,[8,9] including implants placed in augmented bone. The CSRs of suprastructures in GAP patients were 95.9% to 100%. The compromise was the bone and attachment loss at the implants as well as the rate of peri-implantitis and mucositis were higher than in periodontally healthy subjects, and the implant survival rate was lower.[5–9]

Based on the results of this medium-term prospective study about All-on-4 treatment in patients with GAP, the CSR of implants and definitive prostheses were 98.75% and 100%, respectively, and the average peri-implant MBL was 0.8 ± 0.4 mm after 1-year and 1.2 ± 0.3 mm after 7-year follow-up. These preliminary results corresponded well with the results from other existing studies[10–16] of the All-on-4 treatment in the general population or of conventional implant treatment in patients with aggressive periodontitis. This might be the first study about full-arch immediate implant placement and prosthetic rehabilitation in patients with advanced GAP.

4.2 | Specific concerns of GAP patients in China

The average aggressive periodontitis onset age of the patients enrolled in this study was 25 years (ranging from 18 to 29 years) according to their dental care history. However, all the GAP patients in the study came for implant treatment 10-16 years later, when the disease had developed to an advanced stage so that the remaining teeth had a poor or hopeless prognosis for further preservation and periodontal treatment. Therefore, the mean age of these patients was 39.4 years at the time of implant placement. As previous studies reported, although the prevalence of aggressive periodontitis is relatively higher in Asian areas,[3] a large number of Chinese GAP patients procrastinate to seek dental examination and treatment at the onset stage because of awareness, time, cost or psychological concerns until the disease reached an advanced stage. Some young GAP patients also feel reluctant to have all of the periodontally compromised teeth extracted. Therefore, the ages of the GAP patients at the time of implant treatment were much older than the ages of the disease onset in this study, and they suffered from more severe GAP. The attachment loss in the patients between 26-35 years was expected to be greater than the loss in the patients less than 25 years of age.[17]

As was shown in the distribution of teeth lost and extracted, the first molars were the most common teeth lost in GAP patients (17.4% of all the lost teeth). In addition, central incisors had a more obvious dominance in the number of lost teeth in the mandibles compared to the maxillae (14.3% of all the lost teeth in the mandibles). Correspondingly, a total of 148 teeth were extracted from 20 jaws, with an average of 7.4 teeth per jaw. Lateral incisors and canines ranked the highest in the number of teeth extracted in GAP patients. These findings were in accordance with the typical characteristics of aggressive periodontitis.[44]

Attempts to save questionable teeth may jeopardize adjacent teeth and may lead to the loss of bone that is needed for further implant therapy. Such teeth serve as successive microbial reservoirs and sources of implant contamination or other recurrent problem to the patient and detract from the establishment and maintenance of periodontal health in the remainder of the oral cavity.

4.3 | Survival rate and MBL in GAP patients

This study indicated implant CSR of 98.75% in GAP patients after an average of 5-year follow-ups (ranging from 2 to 7 years). Only 1 posterior tilted implant in the maxilla of a male patient was withdrawn at the fourth month after implant placement. The implant survival outcome showed no statistical difference compared with former studies of the All-on-4 protocol in edentulous Chinese patients performed by Di et al. (96.2% at 33.7 months of mean follow-up), and was similar to other studies performed in periodontally compromised patients with immediate function protocols.[10–16] The failed implant was located in the

TABLE 4 Periodontal parameters at last recall visit (after 2-7 y)

	Mean	Standard deviation	Range
Plaque index	1.2	0.4	0-2
Bleeding index	0.5	0.5	0-2
Gingiva index	0.4	0.4	0-2
Probing depth	3 mm	0.5 mm	2-5 mm

maxillary posterior site, probably owing to the poor bone density in the maxilla and a more complicated bone defect in the maxillary posterior region.

Observed peri-implant MBL in this study was low at both short-term and medium-term follow-ups (1-year: 0.8 ± 0.4 mm, 7-year: 1.2 ± 0.4 mm). There was also no statistical difference ($P > .05$) between the upright implants and tilted implants, and the extent and the pattern of marginal bone resorption for upright implants and tilted implants were similar, which was in line with other publications investigating different implant systems.[10–16]

The length and diameter of the implants were selected according to the horizontal and vertical alveolar bone volume and space, and the tilted implants enabled selection of longer implants with better cortical anchorage in optimal positions for prosthetic support.[12] In this study, the MBL showed no statistical difference among different lengths and diameters of implants. The height of the abutments was selected based on the thickness of soft tissue and vertical occlusal space.[25] The selection of angulated abutments was based on the direction of the implants and the angle to gain a relative parallel common insertion path so that rigid prostheses would seat in a passive manner.[14] Although a study by Galindo et al. showed that the abutment height could influence the MBL,[25] in this study, the MBL showed no statistical difference among different height and angle of abutments.

With regard to the usage of different implant systems in this study, the Branemark MK III system was what the implant manufacturers supplied for the All-on-4 treatment in this study at first, the implant manufacturers, and the Nobel Speedy and the Nobel Active system were available later successively.[45–48] The peri-implant MBL indicated no significant difference among the different implant systems.[15,24,45–48]

4.4 | Implant placement sites averted typical bone defects in GAP patients

As was shown in the distribution of implant placement sites, the second premolar was the most common site for posterior tilted implants (70% of all the tilted implants), and 100% of the anterior upright implants were inserted in the site of lateral incisor. This distribution of implant averted the undesirable common bone resorption condition in the first molar and the central incisor areas of patients with aggressive periodontitis, and avoided injury of relevant important anatomic structures. Tilted implants minimized the invasion of surgery and risk of infection in GAP patients, shortened the duration of the treatment, and reduced postoperative reactions such as swelling and pain.

Tilted implants also enabled selection of longer implants with good cortical anchorage in optimal positions for prosthetic support. For the distribution of the length of tilted implants, 15 mm ranked first in the maxillae (57.1%), and 18 mm ranked first in the mandibles (53.8%), which might be otherwise much shorter if those implants were upright placed.

The uneven and wavy alveolar ridge due to the bone resorption pattern of affected teeth was another feature of GAP patients. Extensive alveolar ridge trimming was therefore essential. In addition, the boundary line of the prosthesis and the reduced alveolar ridge were located superior to the patient's smile line for better esthetic effect. This also improved the infection control by mechanically eliminating the reservoirs of pathogens from the extraction sockets.[43]

4.5 | Peri-operative medication and local debridement for infection control of GAP patients

Systemically administered antibiotics pre- and postoperation might play a vital role in the treatment of GAP. Previous studies have shown that systemically administered antibiotics with or without scaling and root planning and/or surgery provided greater clinical improvement in the attachment level change compared to similar periodontal therapies without antibiotics.[49,50] At present, the preferred combination antibiotic therapy for treatment of GAP is 250 mg of amoxicillin thrice daily along with metronidazole 250 mg twice daily for 8 days, which matched the antibiotic regimens we provided to the patients.

Meticulous debridement of the sockets and contaminated soft tissue and chemical rinse by 3% hydrogen peroxide and 0.2% chlorhexidine were also crucial steps for sterilization. Many previous studies have demonstrated the effectiveness of chemical agents like 0.12%-0.2% chlorhexidine and 0.3%-3% hydrogen peroxide in the plaque control of *Aggregatibacter actinomycetemcomitans* and *Porphyromonas gingivalis*, which are the major pathogenic bacteria in aggressive periodontitis.[51–53]

4.6 | Analyses of prosthetic procedures and complications in GAP patients

Fracture was the most common mechanical complication in provisional prostheses at the beginning of this study (15%, the same 3 failed prostheses), and the rate seemed relatively higher than other reported studies of All-on-4 treatment in edentulous patients. Cantilever and implant coping regions were relatively weak areas where stress concentrates, according to strain gauge analysis.[54] Artificial teeth separation in provisional prostheses and loose abutment screws were two other common complications observed in this study. It was partially attributed to the fact that the patients with GAP were generally younger than edentulous patients and characteristically exhibited a shorter vertical distance and a stronger bite force. Some young GAP patients were enthusiastic to try tough and hard food and did not follow the instructions to have soft diet strictly often resulted in overloading of the prosthesis. Some eating habits of Chinese people also aggravate these complications, for example, picking up and biting foods as a whole with chopsticks without cutting them into pieces, tearing meat and dense-textured bread, and chewing heavily with molars. However since 2013, no fractures occurred after the resin bases of the provisional dentures were reinforced with carbon or glass fibers.

From a prosthetic view, the distribution of tilted implants increased the inter-implant space and reduced the number of prosthetic units needed to maintain a cantilever length less than 8 mm (in provisional prostheses) or 15 mm (in definitive prostheses). Good clinical outcomes from studies using four implants to support a full-arch prosthesis

indicated that larger numbers of implants might not be requisite for successful treatment of edentulous jaws.[55–59]

The optimal success rate of definitive prostheses (100%) may partly be contributed to the fabrication of a framework with a precisely tailored structure.

As for functional complications, 1 patient (5.88%) had phonetic changes in the first 2 weeks postrestoration, whereas easier adaptation to the provisional prostheses was found for edentulous patients who used to wear complete removable dentures in previous studies.[14] GAP patients often have anterior teeth labially displaced for years and do not have the experience of wearing dentures. The extraction of these teeth and the new arrangement of the artificial teeth in the correct positions within a few hours resulted in dysphonia and unclear pronunciations. The problem was gradually overcome 1 month later after adaptation and phonetic practice. This may serve as a reminder for clinicians to pay sufficient attention to phonetic problems when it comes to maxillary restoration in GAP patients with remaining fanned out teeth, where appropriate preoperative communication is imperative for patients to have mental preparation.

According to standard All-on-4 protocol, two axially anterior implants were placed in the anterior maxilla parallel to the midline. The straight multiunit abutments were connected to the upright implants while 17° or 30° abutments were connected to the tilted implants.[10] As a matter of fact, labial concavities were frequently observed at the base of the anterior maxillae in GAP patients. To avoid implant apical penetration and bone grafting, anterior implants should be tilted palatally along the axial plane of the maxillae. This made it impossible to achieve a common insertion pathway of prostheses by using straight abutments in the anterior area or to compensate for the discrepancy only by two 30° abutments on the tilted implant in the posterior area. Hence 6 of the 14 (42.9%) 17° or 30° angulated abutments were replaced. Based on the findings in this study, angulated abutments applied in upright implants in the All-on-4 treatment concept did not have a negative effect on the results of implant and prostheses survival rate and MBL.[14]

4.7 | Limitations of surgical guides in Chinese GAP patients

Previous studies have reported that the optimal positions and inclinations of implants may be achieved by using a surgical guide (Nobel Guide AB).[60,61] However, all the cases in this study were performed by an experienced clinician under direct vision without using a surgical guide due to the following considerations. First, a wide range of alveolar ridge trimming in patients with GAP greatly changed the original morphology of the arch, which could cause a mismatch between the surgical guide and the preoperative impression. Second, it was difficult to apply the surgical guide in most of the Chinese patients due to the varied range of mouth openings in Chinese patients.[62,63] Third, the clinical protocol without the surgical guide preparation may significantly reduce the times of visits and overall cost, thus indicating high acceptance among Chinese patients.[14]

4.8 | Persistent oral hygiene and periodontal maintenance of GAP patients

Good periodontal parameters were obtained from the patients with GAP previously. The average PI, mSBI, GI, and PD at the last recall visit (after 2-7 years) were 1.2 ± 0.4, 0.5 ± 0.5, 0.4 ± 0.4, and 3.0 ± 0.5 mm. Persistent care of oral hygiene and adequate periodontal maintenance were crucial to this change. The tissue surface of the prosthesis was designed in "head to head" close contact with the alveolar ridge to ensure convenient and appropriate oral hygiene maintenance. Verbal and written postloading instructions were given to the patients in details including how to use the dental floss, interdental brush, and water pick. Annual routine periodontal examination and supportive periodontal treatment were suggested.[64]

4.9 | High satisfaction of GAP patients

The patients in this study reflected high satisfaction with the overall effect of the All-on-4 immediate protocol. Compared with the former condition, the mastication function and esthetics as well as the quality of life of GAP patients were tremendously improved by immediate implant and restoration, which was in line with the low complaint about esthetics and function. The immediate loading procedure significantly reduced the treatment time and overall cost for Chinese patients. In particular, it avoided months of complete edentulism or the need to wear an uncomfortable removable denture; these factors perfectly met the demand of young GAP patients. In addition, the surgical risks associated with sinus elevation or other augmentation procedures were avoided by tilting the posterior implants, which also improved the acceptance of GAP patients. These advantages greatly benefitted Chinese patients with GAP.[65]

5 | CONCLUSION

Based on the data of this prospective study, full-arch immediate implant and immediate rehabilitation could be a predictable alternative with high satisfaction in patients with GAP in 2- to 7-year follow-ups. The All-on-4 concept averted the severe bone defect areas of aggressive periodontitis. This study had a limited number of patients and was self-controlled. Further clinical studies with longer follow-ups are needed to evaluate implant restoration in GAP patients with immediate function.

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CONFLICT OF INTEREST

The authors report no conflicts of interest related to this study.

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