Scientific Article

Bacteremia of dental origin and antimicrobial sensitivity following oral surgical procedures in children

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Abstract

Methods: *The prevalence and intensity of bacteremia of dental origin were examined in 207 children divided into four groups: a baseline with no surgical intervention (group I), after a single tooth extraction (group II), multiple tooth extraction (group III), and mucoperiosteal flap elevation (group IV). The bacterial isolates were grown using a broth culture (Bactec™) and lysis centrifugation (Paediatric Isolator™) techniques. Dental plaque deposits, gingivitis, spontaneous gingival bleeding and the presence/absence of a dental abscess were recorded and their relationship to bacteremia assessed.*

Results: *The broth culture was positive for group I 11% of the time, group II for 43 %, group III for 54%, and group IV for 43%. The Paediatric Isolator system was found to be a poor method for detecting bacteremia, having only one quarter the sensitivity of the broth culture technique. When organisms were isolated, the intensity of bacteremia ranged from 1 to 3400 colony forming units per milliliter (cfu/mL). Bacterial isolates were susceptible to most of the antibiotics recommended for antibiotic prophylaxis, but erythromycin, gentamycin, penicillin G, and teicoplanin were only 80% (or less) effective in their efficacy while chlorhexidine, amoxicillin, clindamycin, and vancomycin were between 92 and 100% effective.*

Conclusions: *The antibiotics commonly used for an oral and/or parenteral prophylaxis are likely to be effective on at least 80% of occasions with most of them effective on 100% of occasions. (Pediatr Dent 20:1, 28–36, 1998)*

It is well established that a predominantly "viridans" streptococcal bacteremia follows teeth extraction.[1-3] The concern for dental surgeons is that bacteremia from dental extractions and related procedures may result in bacterial endocarditis.[4] To prevent development of this life-threatening disease, the Endocarditis Working Party of the British Society for Antimicrobial Chemotherapy recommends that antibiotic prophylaxis be given for dental extractions, dental scaling, or periodontal surgery.[5] In children, limited studies address bacteremia of dental origin,[2, 3, 6–17] and only two have addressed the efficacy of antibiotic prophylaxis.[3,15] The evidence indicates that the frequency of such bacteremia is lower in children than adults, although the intensity in cfu/mL of blood is usually greater.[18]

The objectives of this study were to estimate the prevalence, intensity, and nature of bacteremia in children following oral surgical procedures and to determine the antibiotic susceptibilities of the most common organisms from such bacteremia. The data obtained would enable baselines to be established: 1) for use in subsequent studies on bacteremia resulting from other dental procedures and 2) to indicate the most suitable antibiotics to use when investigating the efficacy of antimicrobial prophylaxis prescribed to prevent the untoward effects of odontogenic bacteremia in children.

Methods

The subjects were children attending Guy's Dental Hospital (GDH) or The Great Ormond Street Hospital for Children (GOS) who required oral surgery under general anesthesia between 1990 and 1993. They were either healthy children (GDH) or children with a medical disorder that did not require antibiotic prophylaxis, e.g., asthma (GOS). No attempt was made to match the children in the different groups for age. All the children required general anesthesia for minor oral surgery. The project was approved by the ethical committees of both hospitals. Written consent was obtained from the parent or guardian and also from children considered old enough to understand. Patients who had received antibiotics within the previous month were excluded, as were children with known viral disease.

Anesthesia was induced by intravenous thiopentone or propofol or by inhalation of halothane with oxygen and nitrous oxide. Following skin preparation with 1% Povidone-Iodine solution, an intravenous cannula

was inserted into a vein in the antecubital fossa of either arm using standard aseptic technique. A 0.5-mL volume of blood was drawn and discarded. This was to reduce the risk of contamination with skin organisms.

Bacterial dental plaque deposits were recorded using a modification of the O'Leary index by estimating plaque as present or absent on the mesiobuccal, distobuccal, distolingual, and mesiolingual quadrisections of each tooth.[19] The presence or absence of gingival inflammation and spontaneous gingival bleeding, assessed visually for the same tooth surfaces as the plaque estimations, were recorded. The scores for a complete deciduous dentition can range from 0 to 80 and for a complete permanent dentition (excluding third molars) from 0 to 112. This is discussed fully in Franco et al.[20] These scoring methods have the advantage of including data from every tooth surface (quadrisection), they provide a full and sensitive estimate of oral bacterial loading and the true extent of gingival inflammation, and they are reproducible in young children. In addition, the data can be explored using normal distribution statistics.[20] The presence or absence of a dental abscess was also recorded.

Patients were allocated, using a random number table, to one of three study groups: group I–baseline; group II–single extraction; group III–multiple extractions (four or more teeth). For these first groups, children requiring four or more extractions were recruited to the study. Such multiple extractions are a very common procedure at GDH and GOS. The choice of group allocation was made by consulting a random number table. The only change to the normal provision of treatment was that the blood sample was taken at the appropriate point once anesthesia had been achieved, i.e., upon attainment of anesthesia but before placement of the mouth prop for group I; 30 s after the first movement of the tooth for group II, and 30 s after extraction of the last tooth for group III. A further number of patients, those requiring the raising of a mucoperiosteal flap, were assigned to group IV–mucoperiosteal flap. These patients were studied on every occurrence because of the relative infrequency of the procedure. For each subject, 8 mL of venous blood was drawn 30 s after the study procedure was completed.[17] Any further treatment was then completed.

To detect bacteremia, two commercial broth blood culture systems and a lysis centrifugation system were used: the Bactec radiometric system (GDH), the Bactec 760 (GOS) (Beckton Dickinson UK Ltd., Oxford, UK),[21, 22] and the Paediatric Isolator (Isolator Paediatric BDH Ltd., Poole, UK) at both institutions.[23] Three milliliters of blood were inoculated into each of the aerobic and the anaerobic bottles for the Bactec system and a further 1.5 mL of blood for the Paediatric Isolator.

The presence or absence of bacteremia is expressed as the percentage of samples which yielded bacteria (Bactec) and the number of cfu/mL in the blood (Isolator).

TABLE 1. AGE OF PATIENTS, PERCENT POSITIVE BLOOD CULTURES, COLONY FORMING UNITS PER MILLILITER OF BLOOD FROM DENTAL BACTEREMIAS FOLLOWING MINOR ORAL SURGERY IN CHILDREN

	Age (yrs, mo)	*Percent positive*	*cfu/mL*			
			N	*x*	*SD*	*range*
Group I (baseline: no procedure)	8 yrs, 7 mo	11.3%	53	0	0	0
Group II (single extractions)	6 yrs, 9 mo	43.2%	44	0.23	0.77	0–4
Group III (multiple extractions)	7 yrs, 3 mo	54.2%	59	12.7	56.0	0–300
Group IV (mucoperiosteal flap)	11 yrs, 1 mo	43.1%	51	63.4	448.0	0–3200

For percent positive: Chi square = 21.49, df = 3, $P < 0.0001$
Groups II, III, IV significantly greater than Group I

For age: Duncan's multiple range test
I different from II ($P < 0.05$); I different from III ($P < 0.005$)
I different from III ($P < 0.05$); III different from IV ($P < 0.005$)
For cfu/mL: no significant differences using multiple range tests

Bacterial isolates derived from the blood cultures were speciated using standard methods and streptococci identified using the API Strep 20 (Bio Merieux UK Ltd., Basingstoke, UK).[24] The viridans streptococci isolates were frozen in horse blood and stored, together with some samples from a previous study on dental extractions and bacteremia,[17] with the majority from this study. The frozen samples were subsequently revived and investigated for antibiotic and chlorhexidine sensitivity using the agar incorporation technique.[25] This enabled an estimation of the lowest concentration of an antibiotic or other antimicrobial agent which completely inhibits visible surface growth of microorganisms on culture plates—the minimum inhibitory concentration (MIC)—to be made.[25] The MIC was determined for all viridans streptococci and all staphylococci cultured from the blood samples. The antibiotics tested were benzyl penicillin, amoxicillin, erythromycin, clindamycin, vancomycin, teicoplanin (a glycopeptide similar to vancomycin), and gentamicin, all derived from stock chemicals. The antimicrobial agent chlorhexidine was also included, made up from chlorhexidine hydrochloride powder. For streptococci, 5% horse blood was added to the antibiotic plates but not the chlorhexidine plates. The bacterial culture, containing 10^4 cfu of each organism in 1 µL broth, was applied to the agar surface of the culture plates, which contained eight concentrations of the seven antibiotics and the chlorhexidine under test[26] for a total of 64 plates for each organism. The plates were incubated at 37°C for 18–24 h and the MIC determined. In each batch, up to 28 organisms were tested. Two growth control plates were included in each test batch and some organisms were tested twice in the same batch or in successive batches to determine the reproducibility of the results.

Statistical calculations were made using Stata™ for Windows.®[27] These consisted of summary data, Duncan's Multiple Range test for multigroup testing of age and cfu/mL of blood, and the chi square test for the differences in percent positive blood cultures. For differences between plaque, gingivitis, and bleeding indices the Scheffe's multiple comparison tests were used. Correlations were by the Pearson product moment coefficient.

Results

Two hundred and seven children, average age of 8 years, 5 months ± 4 years, 3 months, were included in the study. The mean age of the children in the different groups were significantly different from each other, with groups 1 and IV being greater than groups II and III (Table 1).

Bacteremias

Seventy four of the blood samples (36%) gave positive cultures, producing 113 different isolates of which 64 (57%) were oral streptococci. The majority of cultures, 45 (61%), yielded a single species, while 21 (29%) yielded two species, 6 (8%) yielded three species, and 2 (3%) yielded four species. The proportion of positive cultures and intensity (cfu/mL) for the bacteremia for each procedure are given in Table 1. The organisms isolated in each of the groups are given in Table 2. Stratification by age showed that there was no relationship between and the prevalence of bacteremia.

Periodontal and gingival health in relation to bacteremia

The groups had different levels of bacterial plaque, gingivitis, and gingival bleeding. The examinations were carried out by one examiner (GJR). It is not possible to objectively assess intraexaminer reproducibility for plaque, gingivitis, and bleeding, as immediate rexaminations would be influenced by memory. A suitable alternative is interexaminer reproducibility. This was carried out on conscious children with similar problems (children attending the pediatric dental emergency clinic at GDH) by GJR and another paediatric dentist experienced in this field. For plaque, the k value was 0.9448 and for gingivitis the k value was 0.8114. These indicate very high levels of agreement. The significant differences were due largely to the significantly greater amount of plaque, gingivitis, and gingival bleeding in group III. In addition, there were relatively high levels of plaque in group I (Table 3).

The relationship between the presence of an abscess and a positive blood culture was not significant (chi square = 1.878, df = 2, $P = 0.1706$), nor was that between the use of a nasotracheal tube and bacteremia (chi square 1.248, df = 1, $P = 0.264$). In addition, the relationship between age and the presence of a bacteremia was weak (Pearson correlation coefficient = 0.29). For those children with a dental abscess, the plaque scores were significantly greater than for children with no abscess ($P < 0.0001$). There was no difference in gingival inflammation for children with or without a dental abscess (Table 4).

Although the plaque scores for children with a bacteremia were slightly higher than those for culture negative cases, the difference did not reach significance. This contrasted with gingivitis and gingival bleeding where the scores in the bacteremia group were statistically significantly greater (Table 4).

TABLE 2. ORGANISMS ISOLATED FOLLOWING DIFFERENT ORAL SURGICAL PROCEDURES

Aerobic	N	*Anaerobic*	N
Baseline Bacteremia (Group I)		*Baseline Bacteremia (Group I)*	
Streptococcus oralis	1		
coagulase negative staphylococci	4		
Single Extractions (Group II)		*Single Extractions (Group II)*	
Lactococcus cremoris	1	*Lactococcus cremoris*	1
Streptococcus sanguis	4	*Streptococcus sanguis*	1
Streptococcus mitis	1	*Streptococcus mitis*	1
'viridans' streptococci	6	'viridans' streptococci	8
Gamella haemolysans	1	*Gamella haemolysans*	1
Neisserai spp.	2		
gram positive cocci	1	gram positive cocci	1
gram negative cocci	1		
coagulase negative staphylococci	1	coagulase negative	1
Staphylococcus epidermidis	1		
Propionibacterium spp.	1		
		Diptheroids	1
		anaerobes	2
		Bacteroides spp.	1
Multiple Extractions (Group III)		*Multiple Extractions (Group III)*	
Streptococcus milleri	2	*Streptococcus milleri*	1
Streptococcus sanguis	12	*Streptococcus sanguis*	6
Streptococcus mutans	1	*Streptococcus mutans*	2
Streptococcus mitis	2	*Streptococcus mitis*	2
Streptococcus acidominimus	1		
'viridans' streptococci	5	'viridans' streptococci	3
Streptococcus species	2	Streptococcus species	2
Streptococcus morbillorum	1	*Streptococcus morbillorum*	1
Moraxella catarrhalis	1	*Moraxella catarrhalis*	2
Diptheroids	1	Diptheroids	1
Haemophilus parainfluenzae	2		
coagulase negative staphylococci	3	coagulase negative	1
gram negative bacilli	1	gram negative bacilli	2
Lactococcus cremoris	1	*Lactococcus cremoris*	1
Veillonella spp.	1	Veillonella spp.	1
Neissserai spp.	1		
Corynebacterium spp.	1		

TABLE 2 CONT'D. ORGANISMS ISOLATED FOLLOWING DIFFERENT ORAL SURGICAL PROCEDURES

MucoPeriosteal Flaps (Group IV)		*MucoPeriosteal Flaps (Group IV)*	
Streptococcus sanguis	1	*Streptococcus sanguis*	1
Streptococcus milleri	2	*Streptococcus milleri*	1
Streptococcus mitis	1		
		Streptococcus oralis	1
		Streptococcus spp.	3
'viridans' streptococci	4	'viridans' streptococci	3
Neissseria pharyngis	1	*Neissseria pharyngis*	1
Neissseria species	2	Neissseria species	2
Corynebacterium spp.	2	Corynebacterium spp	1
gram positive bacilli	4	gram positive bacilli	2
		gram positive cocci	2
Diptheroids	1	Diptheroids	1
coagulase negative staphylococci	4	coagulase negative staphylococci	7
Staphylococcus aureus	2	*Staphylococcus aureus*	1
		Veillonella	1
		Bacteroides spp.	1

It is important to note that the genus and species names given in Table 2 are those entered on the laboratory report forms provided by the clinical microbiology consultants. This is the nomenclature commonly used by such laboratories. More recent and extensive work has provided a more reliable and up to date nomenclature (Hardie and Whiley 1994).[36] The importance of this recent work is fully acknowledged. Specific organisms named *Streptococcus lactis* are now named *Lactococcus lactis*. It would be inappropriate, however, to retrospectively change the diagnostic names given by the consultant microbiologists in the laboraties concerned.

Antibiotic sensitivity

The organisms regrown from the frozen horse blood comprised 113 streptococci and 48 staphylococci. The organisms isolated from the cultures are listed together in Table 2 and as can be seen did not show any pattern related to the type of procedure.

The assessment of sensitive or resistant organisms was made on the basis of recommended MIC breakpoint values.[26] These were: amoxicillin 1.0 mg/L, clindamycin 0.5 mg/L, erythromycin 0.5 mg/L, gentamicin 1.0 mg/L, penicillin 0.1 mg/L, teicoplanin 4.0 mg/L, and vancomycin 4.0 mg/L. The breakpoint for chlorhexidine was taken as 50 mg/L (0.05%) which is one-quarter the concentration of the commonly used mouthwash. This is because much of the chlorhexidine is inactivated by salivary glycoproteins in vivo. The overall percentage of oral streptococci sensitive to these concentrations of antibiotics are shown in Figure 1 and of staphylococci in Figure 2.

Reproducibility

Seven organisms were tested separately; three were either the same result or within one dilution for all the antimicrobials and four showed some differences with some antimicrobials. Two organisms were tested twice in the same batch and all results were identical. Three organisms were carried over from one batch to the next and tested a second time. All recorded the same result or within one dilution.

Discussion

In future studies that seek to estimate the intensity of bacteremia, the pour plate technique used by Coulter et al.,[3] or the lysis filtration technique used by Heimdahl et al.,[28] could be expected to yield more satisfactory results.

Broth cultures show that the prevalence of bacteremia for all oral surgical procedures in children is significantly greater than the baseline or resting state. It is of note that the percentage prevalence for nasal intubation is only 9.7% (unpublished data) so for this reason the data were not partitioned by presence or absence of a nasotracheal tube. This is supported by the American Heart Association guidelines on pre-

TABLE 3. LEVELS OF BACTERIAL DENTAL PLAQUE (PI), GINGIVITIS (GI), AND GINGIVAL BLEEDING (BI) IN EACH OF THE GROUPS STUDIED

		PI		*GI*		*BI*	
	N	*mean*	*SD*	*mean*	*SD*	*mean*	*SD*
Group I (baseline: no procedures)	53	10.6	18.9	3.4	7.9	1.6	4.4
Group II (single extractions)	44	4.4	12.3	2.4	3.7	1.4	3.4
Group III (multiple extractions)	59	7.2	7.3	5.6	6.7	4.2	6.5
Group IV (mucoperiosteal flap)	51	2.1	3.4	1.8	3.5	1.3	3.4

For PI, significant differences between groups using Scheffe's multiple comparison test $P < 0.0024$ due largely to high plaque levels in baseline and multiple extraction groups.
For GI, significant differences between groups using Scheffe's multiple comparison test $P < 0.0046$ due largely to differences between multiple extractions and mucoperiosteal groups.
For BI, significant differences between groups using Scheffe's multiple comparison test $P < 0.0019$ due largely to differences

TABLE 4. SIGNIFICANCE OF THE DIFFERENCE BETWEEN MEANS OF GINGIVAL HEALTH INDICES, THE PRESENCE OR ABSENCE OF A BACTEREMIA, AND THE PRESENCE OR ABSENCE OF A DENTAL ABSCESS

	Bacteremia						
	No Bacteremia			*Bacteremia Present*			
	N	*x*	*SD*	N	*x*	*SD*	P
Plaque Index	133	6.2	10.3	74	7.5	16.3	$P = 0.47$
Gingivitis Index	133	2.6	4.9	74	5.5	13.6	$P < 0.03$
Bleeding Index	133	1.4	3.9	74	2.7	5.3	$P < 0.04$
	Dental Abscess						
	No Bacteremia			*Bacteremia Present*			
Plaque Index	144	4.3	10.6	63	12.43	15.6	$P < 0.0001$
Gingivitis Index	144	3.3	9.9	63	4.7	6.9	$P = 0.32$
Bleeding Index	144	1.5	3.5	63	2.9	6.1	$P < 0.04$

vention of bacterial endocarditis which advise against the need for antibiotic prophylaxis "unless it is associated with another procedure for which prophylaxis is recommended".[29] A further cause for concern is the source of the staphylococci. In our study, the percentage of positive cultures from these potential contaminants was 8.6%, a figure consistent with data from other studies carried out in the same hospitals (unpublished data). An attempt to control for skin contamination was made by culturing the 0.5 mL of blood that was first drawn from the cannula and "discarded" into Bactec culture bottles. A series of 51 consecutive cultures obtained in this way gave 5.9% positive cultures for the discarded 0.5-mL samples. It is our contention that that percentage of positive isolates for staphylococci of 8.6% represents a true level of bacteremia due, presumably, to transient oral colonisation by staphylococci. If this figure is not accepted, the 5.9% known contamination from the discarded 0.5% mL still leaves a minimum true bacteramia of 2.7% due to staphylocicci. This is consistent with published data.[30]

As might be expected, the prevalence following multiple extractions (group III) is greater than for a single extraction (group II) although not statistically significant. The prevalence for group IV (mucoperiosteal) is midway between group II and group III, which is surprising when the extensive dentogingival trauma caused by the elevation of a mucoperiosteal flap is considered. However, most of the group IV children were having elective surgery prior to orthodontic treatment, and their standard of oral health was good while the surgery for groups II and III was usually to relieve pain or infection associated with oral neglect. Although

the plaque, gingivitis, and gingival bleeding scores in the baseline (nontreatment) group seemed high, the finding may be explained by the fact that these children were in the same category as those in groups II and III, i.e., having surgery for the relief of pain and infection associated with oral neglect.

The organisms isolated are typical of those identified by others following oral surgical procedures.[2, 28] The high proportion of *viridans streptococci* is a significant finding with important implications for the dental management of children with congenital or aquired heart disease, as this group of organisms is frequently found to be involved in bacterial endocarditis.

The range of antibiotics studied includes all those currently recommended for antibiotic prophylaxis, and from the results, most should effectively counteract a dental bacteremia. Nevertheless, failure of antibiotic prophylaxis has been documented[31–33] and in a concurrent study on children with congenital heart disease, there is still detectable bacteremia in 15% of the cases, despite the use of recommended antibiotic prophylaxis (unpublished data). While these failures will not result in endocarditis on all occasions, other ways of reducing the risk need to be considered. When used alone, chlorhexidine has been shown to be only partially effective in reducing the prevalence of dental bacteremia.[34]

Another interesting finding is the absence, on the one hand, of a significant relationship between bacterial plaque scores and bacteremia and, on the other hand, the highly significant relationship between gingival inflammation or gingival bleeding and bacteremia. One explanation is that the visible plaque has not been present for long enough to provoke a level of inflammation that would render the underlying tissues susceptible to microbial ingress, whereas overt inflammation indicates more established disease which allows readier access of crevicular organisms to the blood stream. Another explanation is that much of the plaque is too superficially (coronally) placed on the tooth surface(s) to be readily carried into the crevicular and subgingival tissues during surgery.

The significant relationship between the presence of a dental abscess and high plaque scores probably reflects the poor level of oral health care in the children with more severe disease. It may also be related to discomfort in the area of the abscessed tooth and a tendency to avoid chewing or cleaning on that side of the mouth which, in turn, leads to increased plaque accumulation.

The present study confirms the high incidence of bacteremia following minor oral surgical procedures in children although at a lower level than has been shown in adults. These data are consistent with findings of other reports of dental bacteremia in children although the figures are slightly lower.[2, 3] The viridans streptococci isolated following extraction of a single tooth are, to a great extent, susceptible to the antibi-

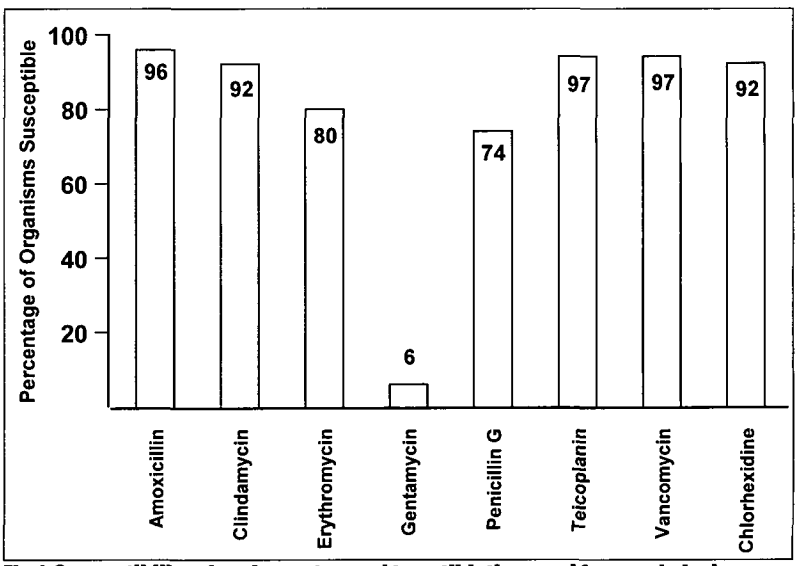

Fig 1. Susceptibility of oral streptococci to antibiotics used for prophylaxis.

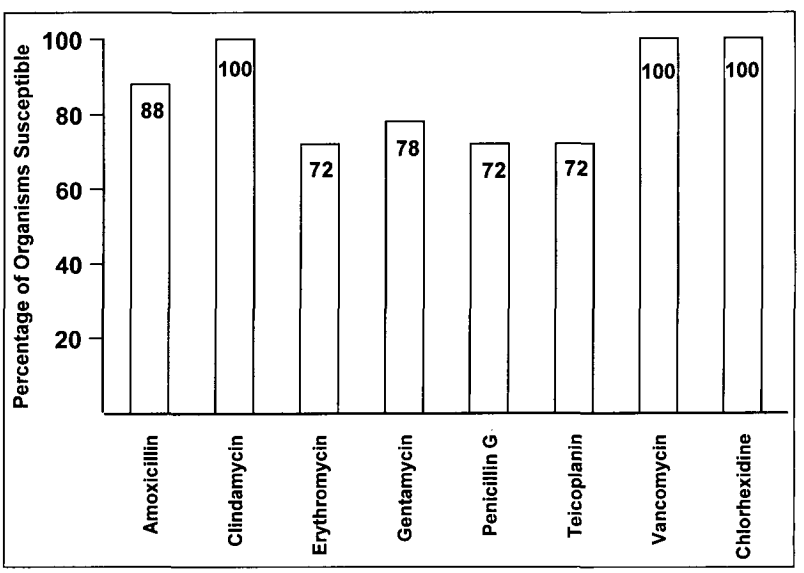

Fig 2. Susceptibility of staphylococci to antibiotics used for prophylaxis.

otics commonly recommended for prophylaxis. The small percentage of nonsensitive organisms indicates a possible reason for failure of prophylaxis.[35]

It is of note that the use of antibiotics administered systemically does not reduce the bacteremia, simply killing or quenching the microorganisms once they gain entry to the circulation. The large proportion of cases of bacterial endocarditis caused by *viridans streptococci* are the basis for the antibiotic prophylaxis recommended by The American Heart Association[29] in the US and the Endocarditis Working Party in the UK.[5]

The clear and significant relationship between dental bacteremia and the presence of gingival inflammation and gingival bleeding suggests that improved oral health care might reduce the prevalence of dental bacteremia following oral surgical procedures in children. It is tempting to suggest that this may be as important a method of reducing the risk of bacterial endocarditis as antibiotic prophylaxis. Clearly, further work is required to test such a hypothesis.

Conclusions

The above work confirms and extends that of other investigators in this field. The most important findings are

1. Bacteremia of dental origin occurs following all minor oral surgical procedures in children with multiple extractions causing the greatest proportion of positive blood cultures.
2. The antibiotics commonly used for oral and/or parenteral prophylaxis are likely to be effective on at least 85% of occasions, with most of them effective on 100% of occasions.
3. Further work is needed to investigate the role of lowered oral bacterial loading and improved tissue integrity in reducing the prevalence of bacteremia of dental origin.

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